The Electrochemical Society . . .

117th Meeting

Chicago
May 1, 2, 3, 4, and 5, 1960

LOCAL COMMITTEE

General Chairman
E. L. Koehler

Advisor
H. T. Francis

Hotel Arrangements
Ralph Hovey

Finance and Registration
Ralph Wehrmann

Entertainment
C. A. Hampel

Host Committee
S. Evans

Ladies' Program
Mrs. E. L. Koehler, Chairman
Mrs. C. A. Hampel, Advisor and Vice-Chairman
Mrs. R. Hovey

Chicago Program

THE ELECTROCHEMICAL SOCIETY

One Hundred and Seventeenth Meeting

May 1, 2, 3, 4, and 5, 1960

Sunday through Thursday

CONDENSED TECHNICAL PROGRAM

Monday, May 2, 1960

Electric Insulation (Abstracts 1-9) 9:00 A.M.-12:00 M.; 2:00-5:00 P.M. (Parlor D, Mezzanine)

Electronics-Luminescence (Abstracts 40-54) 9:00 A.M.-12:00 M.; 2:00-4:45 P.M. (Lincoln-Douglas Rooms, 18th floor)

Electronics-Semiconductors (Abstracts 78-93) 9:15 A.M.-12:15 P.M.; 2:00-5:30 P.M. (Grand Ballroom, 19th floor)

Electrothermics and Metallurgy-Vanadium (Abstracts 121-132) 9:15-11:55 A.M.; 1:30-4:55 P.M. (Chicago Room, Mezzanine)

Industrial Electrolytic (Abstracts 178-185) 10:00 A.M.-12:00 M.; 2:45-4:45 P.M. (Illinois Room, Mezzanine)

Tuesday, May 3, 1960

Electric Insulation (Abstracts 10-20) 9:00 A.M.-12:00 M.; 2:00-4:30 P.M. (Parlor D, Mezzanine)

Electronics-Luminescence (Abstracts 55-68A) 9:00-11:55 A.M.; 2:00-4:25 P.M. (Lincoln-Douglas Rooms, 18th floor)

Electronics-Semiconductors (Abstracts 94-104) 9:00 A.M.-12:05 P.M.; 2:00-4:30 P.M. (Grand Ballroom, 19th floor)

Electrothermics and Metallurgy-Iron Ores (Abstracts 133-140) 8:30-11:30 A.M.; 2:45-4:50 P.M. (Illinois Room, Mezzanine)

Electrothermics and Metallurgy-Rhenium (Abstracts 154-164) 9:00-11:40 A.M.; 2:00-4:10 P.M. (Press Gallery, 18th floor)

Theoretical Electrochemistry—Industrial Electrolytic (Abstracts 186-190) 9:15 A.M.-12:00 M.; 2:00-4:30 P.M. (Century Room 19th floor)

Wednesday, May 4, 1960

Electric Insulation (Abstracts 21-30) 9:00-11:30 A.M.; 2:00-4:30 P.M. (Parlor D, Mezzanine)

Electronics-General (Abstracts 36-39) 2:15-3:55 P.M. (Chicago Room, Mezzanine)

Electronics—Luminescence (Abstracts 69-77B) 9:00-11:55 A.M.; 2:00-4:30 P.M. (Lincoln-Douglas Rooms, 18th floor)

Electronics-Semiconductors (Abstracts 105-120) 9:00 A.M.-12:00 M.; 2:00-4:45 P.M. (Grand Ballroom, 19th floor)

Electrothermics and Metallurgy-Iron Ores (Abstracts 141-149) 9:30 A.M.-12:00 M.; 2:00-5:05 P.M. (Illinois Room, Mezzanine)

Electrothermics and Metallurgy-Rhenium (Abstracts 165-174) 9:15-11:25 A.M.; 2:00-4:10 P.M. (Press Gallery, 18th floor)

Theoretical Electrochemistry—Industrial Electrolytic (Abstracts 191-195) 9:30 A.M.-12:00 M.; 2:00-4:30 P.M. (Century Room, 19th floor)

Thursday, May 5, 1960

Electric Insulation (Abstracts 31-35) 9:00 A.M.-12:00 M. (Parlor D, Mezzanine)

Electrothermics and Metallurgy-Iron Ores (Abstracts 150-153) 9:30 A.M.-12:00 M.; 2:00-4:00 P.M. (Illinois Room, Mezzanine)

Electrothermics and Metallurgy-Refractory Metals (Abstracts 175-177) 9:30-11:00 A.M. (Press Gallery, 18th floor)

Theoretical Electrochemistry (Abstracts 196-210) 9:00-11:20 A.M.; 2:00-4:40 P.M. (Lincoln-Douglas Rooms, 18th floor)

GENERAL INFORMATION

Convention Headquarters is the LaSalle Hotel, LaSalle at Madison St., Chicago 2, Ill.

Rates per day for rooms, with bath, are: single room, $7.50, 8.50, 9.50, 10.00, 10.50, 11.50, 13.50, 15.50; double-bed room, $11.00, 12.00, 13.00, 13.50, 14.00, 15.00, 17.00, 19.00; twin-bed room, $15.00, 17.00, 18.00, 18.50, 19.00, 20.00; 2 rooms with connecting bath, for 2—$17.00, for 3—19.00, for 4—21.00; parlor, double-bed room, for 1—$16.00, 17.50, for 2—19.50, 20.00; parlor, twin-bed room, $33.50, 45.00 50.00, 55.00; parlor, two bedrooms, $52.00, 62.50, 85.00.

Requests for room reservations should be mailed to the LaSalle Hotel, LaSalle at Madison St., Chicago 2, Ill. BE SURE to state that you will be attending The Electrochemical Society Meeting. If your wife will be attending, be sure to indicate this on your request for reservation.

The Office of the Secretary is Parlor A, Mezzanine.

The Chicago Local Section Headquarters is Parlor B, Mezzanine.

Ladies' Headquarters is Parlor F, Mezzanine.

All technical sessions will be held on the Mezzanine, 18th, and 19th floors.

REGISTRATION

The registration desk will be in the Century Room, 19th floor, on Sunday and Monday, May 1 and 2, and in the 19th floor foyer Tuesday through Thursday, May 3-5. The registration schedule is:

Sunday, May 1—3:00 to 9:00 P.M.
Monday, May 2—8:00 A.M. to 4:00 P.M.
Tuesday, May 3—8:00 A.M. to 4:00 P.M.

Wednesday, May 4—8:00 A.M. to 4:00 P.M.
Thursday, May 5—8:00 A.M. to 12:00 M.

Registration fees are:

Members, guest speakers, coauthors	$ 7.00
Nonmembers	13.00*
Ladies	5.00
Thursday only	5.00
Student Members	Complimentary
Students	2.00

* If a nonmember fills out an application form and subsequently is elected to membership in the Society, the difference between the nonmember and member registration fee will be applied to his first year's dues.

INFORMATION ABOUT CHICAGO

Information about places of interest and other attractions will be available at the Society's registration desk at the LaSalle Hotel.

SYMPOSIA AND ROUND TABLES

The Electric Insulation Division has scheduled a three-day symposium on Electrolytic Capacitors, as well as a general session.

The Electronics Division has scheduled a general session, and six sessions on Luminescence; the Semiconductor Group has symposia on: Crystal Growth; Physical Chemistry of Semiconductors; Compound Semiconductors, Surfaces; Oxide Films; Diffusion; and Device Technology.

The Electrothermics and Metallurgy Division has scheduled symposia on: Vanadium; Methods of Reducing Iron Ores; Rhenium: and Refractory and Reactive Metals.

The Industrial Electrolytic Division has scheduled two general sessions.

The Theoretical Electrochemistry Division and the Industrial Electrolytic Division have scheduled a Joint Symposium on Electrochemical Engineering including Applied Electrode Kinetics, Transport Processes in Electrolytic Cells, Distribution of Potential and Current in Electrolytic Cells, and Scale Up and Measurements on the Plant Scale.

The Theoretical Electrochemistry Division has scheduled two general sessions.

GENERAL FUNCTIONS

Symposia Chairmen Breakfasts

On Monday, Tuesday, Wednesday, and Thursday, May 2, 3, 4 and 5, special breakfasts will be held for symposia chairmen. On the day on which he presides at a symposium, each chairman should be in the Coffee Room, lower Lobby, LaSalle Hotel, where a special table will be set up, at 7:45 A.M.

Monday Evening Mixer

On Monday, May 2, all those registered at the meeting are invited to attend the mixer in the Illinois Room, Mezzanine, from 8:00 to 10:00 P.M. Beer, soft drinks, and snacks will be served on a complimentary basis. Admission is by registration badge.

Tuesday Society Luncheon and Business Meeting

The Electrochemical Society Luncheon and Business Meeting will be held on Tuesday, May 3, at 12:15 P.M. in the Illinois Room, Mezzanine. Bill Veeck, President of the American League Champion Chicago White Sox, is guest speaker.

Tuesday Palladium Medal Address

Professor A. N. Frumkin, Director of the Electrochemical Institute of the USSR, will deliver the Palladium Medal Address at 5:00 P.M. on Tuesday, May 3, in the Illinois Room, Mezzanine.

Tuesday Evening Reception and Banquet

A reception honoring President and Mrs. W. C. Gardiner will be held at 6:30 P.M. on Tuesday, May 3, in the Grand Ballroom, 19th floor. Cocktails will be served from 6:30 to 7:30 P.M., followed by dinner at 7:30 P.M. Dr. Gardiner will deliver the Presidential Address.

Wednesday Evening Party

Arrangements have been made with the famous Chez Paree for an evening including a cocktail hour, dinner, and entertainment. Red Skelton is scheduled to be featured that evening. (Price $10.00, including gratuity. Drinks ordered at the dinner table will be at the individual's expense.) Tickets for this function will be available at the Society's registration desk. Be at Chez Paree at 6:45 P.M.

LADIES' PROGRAM

All the ladies are invited to make Parlor F, Mezzanine, their headquarters during their stay in Chicago. A coffee hour will be held from 10:00 to 11:00 A.M. Monday through Thursday, May 2 to 5, in Parlor F. Members of the Ladies' Committee will be there to give information and assist in any way they can to make the stay a pleasant one.

Monday, May 2—Coffee hour at 10:00 A.M. The ladies will meet at 12:30 P.M. at the Kungsholm Restaurant, 100 East Ontario St. They will see the Puppet Opera at 2:00 P.M. Monday evening the ladies are invited to attend the Mixer from 8:00 to 10:00 in the Illinois Room, Mezzanine (see General Functions).

Tuesday, May 3—Coffee hour at 10:00 A.M. The ladies are invited to attend the Society Luncheon at

12:15 P.M. in the Illinois Room, Mezzanine, and the Reception and Banquet at 6:30 P.M. in the Grand Ballroom, 19th floor (see General Functions). The afternoon is left open.

Wednesday, May 4—Coffee hour at 10:00 A.M. The ladies will meet at Fritzel's Restaurant, State at Lake St., at 12:00 M., for lunch. Buses will leave there at 1:30 P.M. for a visit to the Oriental Institute and the Rockefeller Memorial Chapel at the University of Chicago. If time permits and the ladies so desire, the Museum of Science and Industry may be visited. The ladies are welcome to attend the party at Chez Paree at 6:45 P.M. (see General Functions).

Thursday, May 5—Coffee hour at 10:00 A.M.

LUNCHEONS AND BUSINESS MEETINGS OF DIVISIONS

Electric Insulation Division Luncheon and Business Meeting, Wednesday, May 4, at 12:30 P.M. in the LaSalle Room, 18th floor.

Electronics Division Luncheon and Business Meeting, Wednesday, May 4, at 12:15 P.M. in the Chicago Room, Mezzanine.

FALL MEETING
at the
Shamrock Hotel
HOUSTON, TEXAS
October 9, 10, 11, 12, and 13, 1960

Sessions probably will be scheduled on:

Batteries
Corrosion
Electrodeposition
Electronics-Semiconductors
Electrothermics and Metallurgy

Abstracts for the Houston Meeting (*not exceeding 75 words in length*) must reach Society Headquarters, 1860 Broadway, New York 23, N. Y., *not later than June 1, 1960* to be included in the program. *Please indicate on the abstract for which Division's symposium the paper is to be scheduled and underline the name of the author who will present the paper.*

Papers submitted for presentation at the meeting become the property of The Electrochemical Society and may not be published elsewhere, in whole or in part, unless permission is requested and granted by the Society. Papers already published elsewhere, or submitted for publication elsewhere, are not acceptable for oral presentation except on invitation by a Divisional Program Chairman.

Electrothermics and Metallurgy Division Luncheon and Business Meeting, Wednesday, May 4, at 12:30 P.M. in Parlor E, Mezzanine.

Industrial Electrolytic Division Luncheon and Business Meeting, Monday, May 2, at 12:30 P.M. in the Illinois Room, Mezzanine.

Theoretical Electrochemistry Division Business Meeting, Thursday, May 5, at 11:30 A.M. in the Lincoln-Douglas Rooms, 18th floor.

BOARD AND COMMITTEE MEETINGS

Sunday, May 1, 2:00 P.M.—Meeting of the **Board of Directors,** Lincoln-Douglas Rooms, 18th floor.

Monday, May 2, 2:00 P.M.—Meeting of the **Convention Advisory Committee,** LaSalle Room, 18th floor.

Monday, May 2, 4:30 P.M.—Meeting of the **Council of Local Sections,** Press Gallery, 18th floor.

Monday, May 2, 5:00 P.M.—Meeting of the **Editorial Staff** of the Journal, La Salle Room, 18th floor.

Wednesday, May 4, 5:00 P.M.—Meeting of the **Membership Committee,** LaSalle Room, 18th floor.

Thursday, May 5, 12:00 M.—Meeting of **General Chairmen of Future Meetings.** Meet in the Office of the Secretary, Parlor A, Mezzanine. Luncheon will be held in the Lotus Room, Lobby.

COST OF VARIOUS FUNCTIONS

(other than registration)

Please buy tickets as early as possible.

Symposia Chairmen Breakfasts-Standard menu prices	
Monday Evening Mixer	Complimentary
Division Luncheons	$ 4.00
Tuesday Society Luncheon	4.50
Tuesday Reception and Banquet, men	9.00
ladies	7.00
Ladies' Luncheons and functions, each	1.00
Wednesday Evening, Chez Paree	10.00

JOURNALS

Copies of the January, February, March, and April issues of the "JOURNAL OF THE ELECTROCHEMICAL SOCIETY" will be available at the registration desk. The price of a single copy of the Journal is $1.25 to members and $1.75 to nonmembers.

EXTENDED ABSTRACTS

The Electronics Division is making available an extended abstract booklet containing 1000-word abstracts of most of the papers presented before the Electronics Division at the Chicago Meeting. Copies will be available at the registration desk or may be obtained about two weeks before the meeting by request to A. E. Hardy, Radio Corp. of America, New Holland Pike,

Lancaster, Pa. Price $3.50 with a discount of $00.50 per copy for orders accompanied by payment and requiring no invoice.

DISCUSSION

No recordings will be made of oral discussions. Those contributing to the discussion of a paper and desiring their remarks to be published will be supplied by the symposium chairman with a printed form on which any discussion may be written. These forms should be given to the Secretary-Treasurer of the Division or to the Managing Editor of the Journal after the session; they can be mailed to the Managing Editor of the Journal, 1860 Broadway, New York 23, N. Y. The discussion will then be referred to the author for reply. Publication of the discussion and the comments of the author depends on publication of the article in the Journal.

Written discussion should be submitted within two months following publication of the article in the Journal. A Discussion Section is published semiannually in the Journal.

EMPLOYMENT POSTERS

Companies which desire to recruit employees at the Columbus Meeting will have posters to this effect on a board near the registration desk. Companies are requested to confine their announcements to this board.

NOTE

In the Index to Authors, the abstract number is used. Address of each author is included with the abstract.

Technical Program

Chicago Meeting

ELECTRIC INSULATION

Monday, May 2, 1960
Electrolytic Capacitors
with C. C. Houtz presiding

(PARLOR D, Mezzanine)

9:00 A.M.—Introductory remarks by A. J. Sherburne
9:15 A.M.—"Electrolytic Oxide Films" by J. Burnham (Abstract No. 1)
10:10 A.M.—"Conduction, Storage, and Photoelectric Phenomena in Anodic Aluminum Oxide Films" by Kurt Lehovec (Abstract No. 2)
11:05 A. M.—"Impedance Characteristics of Anodic Oxides" by L. Young (Abstract No. 3)

MEETING ROOM SCHEDULE

Meeting	Monday		Tuesday		Wednesday		Thursday	
	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.
Electric Insulation	G	G	G	G	G	G	G	
Electronics—General						F		
—Luminescence	C	C	C	C	C	C		
—Semiconductors	A	A	A	A	A	A		
Electrothermics and Metallurgy								
—Refractory Metals							D	
—Iron Ores			E	E	E	E	E	E
—Rhenium			D	D	D	D		
—Vanadium	F	F						
Industrial Electrolytic	E	E						
Theoretical Electrochemistry—Industrial Electrolytic			B	B	B	B		
Theoretical Electrochemistry							C	C

A = Grand Ballroom; B = Century Room; C = Lincoln-Douglas Rooms; D = Press Gallery; E = Illinois Room; F = Chicago Room; G = Parlor D.

Electric Insulation (cont'd)
Monday, May 2, 1960
Electrolytic Capacitors (cont'd)
with R. A. Ruscetta presiding
(PARLOR D, Mezzanine)

2:00 P.M.—"Tantalum Anode Reactions" by Donald Stephenson and Robert Russ (Abstract No. 4)

2:30 P.M.—"Dielectric Characteristics of Tantalum Anodic Oxide Films As Related to Film Structure" by D. Mohler (Abstract No. 5)

3:00 P.M.—"Hydrated Oxide Films on Aluminum" by Dietrich Altenpohl (Abstract No. 6)

3:30 P.M.—"Anodic Formation of Aluminum Oxide Films, I. The Influence of Surface Preparation on Film Properties" by W. E. Tragert and J. R. Rairden (Abstract No. 7)

4:00 P.M.—"Anodic Formation of Aluminum Oxide Films, II. Effect of Various Electrical Forming Conditions on Film Properties" by W. E. Tragert and J. R. Rairden (Abstract No. 8)

4:30 P.M.—"Determination of the Thickness of Thin Porous Oxide Films on Aluminum" by M. S. Hunter and P. F. Towner (Abstract No. 9)

Electric Insulation (cont'd)
Tuesday, May 3, 1960
Electrolytic Capacitors (cont'd)
with C. C. Houtz presiding
(PARLOR D, Mezzanine)

9:00 A.M.—"Capacitor Grade Tantalum" by L. H. Belz (Abstract No. 10)

9:30 A.M.—"Measurement of the Specific Surface Area of Tantalum Powders and Sintered Anodes" by W. G. Guldner and C. C. Houtz (Abstract No. 11)

10:00 A.M.—"Some Physical Properties of Metallic Tantalum" by J. I. Budnick (Abstract No. 12)

10:30 A.M.—"Low-Temperature Sintering of Tantalum Anodes" by C. J. B. Fincham and G. J. Villani (Abstract No. 13)

11:00 A.M.—"Determination of the Thickness of Anodic Oxide Films by the Spectrophotometric Method in Conjunction with the Abèles Method for the Refractive Index" by L. Young and J. E. Orme (Abstract No. 14)

11:30 A.M.—"Electrolytic Etching of Dense Tantalum" by A. L. Jenny and R. A. Ruscetta (Abstract No. 15)

12:15 P M.—Society Luncheon and Business Meeting in the Illinois Room, Mezzanine. Bill Veeck, President of the American League Champion Chicago White Sox, is guest speaker.

Electric Insulation (cont'd)
Tuesday, May 3, 1960
Electrolytic Capacitors (cont'd)
with R. A. Ruscetta presiding
(PARLOR D, Mezzanine)

2:00 P.M.—Niobium (Columbium) Solid Electrolytic Capacitors" by N. Schwartz, M. Gresh, and S. Karlik (Abstract No. 16)

2:30 P.M.—"Columbium (Niobium) Electrolytic Capacitors" by A. Shtasel and H. T. Knight (Abstract No. 17)

3:00 P.M.—"Silicon Nitride Thin Film Dielectric" by C. R. Barnes and C. R. Geesner (Abstract No. 18)

3:30 P.M.—"Properties of Anodically Formed Oxide Films on Tungsten" by H. W. Pitman and D. C. Hamby (Abstract No. 19)

4:00 P.M.—"Ion Size Effect and Mechanism of Electrolytic Rectification" by P. F. Schmidt, F. Huber, and R. F. Schwarz (Abstract No. 20)

5:00 P.M.—Palladium Medal Address by A. N. Frumkin in the Illinois Room, Mezzanine.

Electric Insulation (cont'd)
Wednesday, May 4, 1960
Electrolytic Capacitors (cont'd)
with L. Young presiding

(PARLOR D, Mezzanine)

9:00 A.M.—"The A-C Properties of Tantalum Solid Electrolytic Capacitors" by D. A. McLean (Abstract No. 21)

9:30 A.M.—"A Mathematical Model for the Porous Type Tantalum Anode Capacitor" by J. S. Fisher (Abstract No. 22)

10:00 A.M.—"Cathodic Depolarization in Tantalum Electrolytic Capacitors" by T. C. O'Nan (Abstract No. 23)

10:30 A.M.—"Cell and Thermoelectric Effects of Tantalum Electrolytic Capacitors" by J. M. Law and W. C. Richards (Abstract No. 24)

11:00 A.M.—"A Selective Electrochemical Etching Procedure to Improve D-C Characteristics of Oxide Film Capacitors" by R. W. Berry, N. Schwartz, M. J. Urban, and M. Gresh (Abstract No. 25)

12:30 P.M.—Electric Insulation Division Luncheon and Business Meeting in the LaSalle Room, 18th floor. A. J. Sherburne will speak on "Electrical Insulation in Retrospect."

Electric Insulation (cont'd)
Wednesday, May 4, 1960
Electrolytic Capacitors (cont'd)
with J. Burnham presiding

(PARLOR D, Mezzanine)

2:00 P.M.—"Equivalent Series Resistance of Anodically Formed Oxide Films on Aluminum" by W. J. Bernard (Abstract No. 26)

2:30 P.M.—"Factors Determining Allowable Ripple Current at Various Frequencies in Aluminum Electrolytic Capacitors" by R. Lane and A. Bennett (Abstract No. 27)

3:00 P.M.—"500°C Capacitors" by R. J. Stamets and R. A. West (Abstract No. 28)

3:30 P.M.—"A Novel Low Voltage Electrolytic Capacitor without Conventional Spacers" by A. J. Catotti and R. A. West (Abstract No. 29)

4:00 P.M.—"Volume Resistivity of Ammonium Ethylene Glycoborate Electrolytes" by C. C. Houtz (Abstract No. 30)

Electric Insulation (cont'd)
Thursday, May 5, 1960
General Session
with A. H. Sharbaugh presiding

(PARLOR D, Mezzanine)

9:00 A.M.—"Electrical Properties of Some Aliphatic Acids and Alcohols" by A. M. Parks (Abstract No. 31)

9:30 A. M.—"Effects of Tropical Exposure on the Electrical Properties of Insulating Materials" by L. J. Frisco (Abstract No. 32)

10:00 A.M.—"Effect of Heat on the Electrical Properties of Paper" by L. H. Wirtz and T. D. Callinan (Abstract No. 33)

10:30 A.M.—"The Electric Strength of Insulating Liquids" by A. H. Sharbaugh (Abstract No. 34)

11:15 A.M.—"Dielectric Properties of Very Thin Films of Liquid Dielectrics" by T. Salomon (Abstract No. 35)

ELECTRONICS

Wednesday, May 4, 1960
General Electronics
with A. E. Martin presiding

(CHICAGO ROOM, Mezzanine)

2:15 P.M.—"Micromodular Solid Tantalum Capacitors" by A. W. H. Smith (Abstract No. 36)

2:40 P.M.—"Digital Programming Unit for Automatic Temperature Control" by N. L. Hozak, J. S. Cook, and D. R. Mason (Abstract No. 37)

3:05 P.M.—"An Economical, Automatic, Differential Thermal Analysis System" by C. E. Barnes and D. R. Mason (Abstract No. 38)

3:30 P.M.—"Electroluminescent-Piezoelectric Flat Panel Displays" by S. Nudelman, J. Lambe, J. Mudar, and G. Trytten (Abstract No. 39)

ELECTRONICS—LUMINESCENCE

Monday, May 2, 1960
with A. L. Smith presiding

(LINCOLN-DOUGLAS ROOMS, 18th floor)

9:00 A.M.—"Phenomenological Theory of Luminescence of Nonphotoconducting Phosphors" by Yasuo Uehara (Abstract No. 40)

9:45 A.M.—"Irreversible Thermodynamics of Solid-State Luminescence" by F. E. Williams (Abstract No. 41)
10:05 A.M.—"Shape of Absorption Bands in Solids" by J. J. Markham (Abstract No. 42)
10:35 A.M.—"Atomic Wave Functions of Activators" by K. H. Butler (Abstract No. 43)
10:55 A.M.—"The Significance of Measurements of the Temperature Dependence of Luminescence Intensity" by C. H. Haake (Abstract No. 44)
11:20 A.M.—"Absolute Spectral Reflectance of Phosphors" by J. E. Eby (Abstract No. 45)
11:40 A.M.—"Infrared Spectroscopy in Phosphor Research" by M. J. B. Thomas and C. W. Jerome (Abstract No. 46)

Electronics—Luminescence (cont'd)
Monday, May 2, 1960
with C. A. Brown presiding

(LINCOLN-DOUGLAS ROOMS, 18th floor)

2:00 P.M.—"Factors Influencing Luminescent Emission Studies of the Rare Earth Ions" by L. G. Van Uitert (Abstract No. 47)
2:20 P.M.—"Some Optical Properties of Powder and Crystal Halophosphate Phosphors" by P. D. Johnson (Abstract No. 48)
2:40 P.M.—"Energy Levels of the Antimony Center in Halophosphates" by F. E. Williams (Abstract No. 49)
3:00 P.M.—"Lead- and Manganese-Activated Calcium-Cadmium Silicate Phosphors" by Yasuo Uehara, Yoshimasa Kobuke, Isoo Masuda, and Takashi Kushida (Abstract No. 50)
3:25 P.M.—"Luminescence vs. Composition Studies of Complex Zinc and Cadmium Orthophosphates Containing Sodium and Lithium" by A. L. Smith (Abstract No. 51)
3:45 P.M.—"Cadmium Phosphate Phosphors" by R. C. Ropp (Abstract No. 52)
4:05 P.M.—"Luminescence of AlN" by I. Adams, J. W. Mellichamp, and G. A. Wolff (Abstract No. 53)
4:25 P.M.—"Crystal Structure and Spectra of Alkali Halide Phosphors" by F. D. Klement (Abstract No. 54)

Electronics—Luminescence (cont'd)
Tuesday, May 3, 1960
with Seymour Keller presiding

(LINCOLN-DOUGLAS ROOMS, 18th floor)

9:00 A.M.—"On the Hydrogen-Like Model for Traps in Zinc Sulfide" by G. Curie, N. Arpiarian, P. Guéret, and D. Curie (Abstract No. 55)
9:25 A.M.—"A Numerical Table for the Computation of Trap Depths from Thermoluminescence Experiments" by G. Curie and D. Curie (Abstract No. 56)
9:50 A.M.—"Gold-Activated (Zn,Cd)S Phosphors" by

M. Avinor (Abstract No. 57)

10:10 A.M.—"Low-Temperature Luminescence of ZnSCdS Phosphors" by R. W. A. Gill and S. Rothschild (Abstract No. 58)

10:30 A.M.—"Infrared Stimulation and Quench of Zinc Sulfide Phosphors" by C. C. Klick (Abstract No. 59)

10:50 A.M.—"Synthesis and Crystallography of Structurally Pure Cubic and Hexagonal Single Crystals of ZnS" by Harold Samelson and V. A. Brophy (Abstract No. 60)

11:15 A.M.—"Infrared Absorption of n-Type (Zn,Cd)S" by R. M. Potter (Abstract No. 61)

11:35 A.M.—"Formation of Phosphor Films by Evaporation" by L. R. Koller (Abstract No. 62)

12:15 P.M.—Society Luncheon and Business Meeting in the Illinois Room, Mezzanine. Bill Veeck, President of the American League Champion Chicago White Sox, is guest speaker.

Electronics—Luminescence (cont'd)
Tuesday, May 3, 1960
with Frank Ullman presiding
(LINCOLN-DOUGLAS ROOMS, 18th floor)

2:00 P.M.—"Continuous Films of II-VI Phosphors and Photoconductors Made by Vapor Reaction" by D. A. Cusano (Abstract No. 63)

2:25 P.M.—"Transparent and Powder Phosphor Screens under High Ambient Illumination" by A. E. Hardy (Abstract No. 64)

2:50 P.M.—"Mechanism of Depreciation of Electroluminescent Phosphors" by I. L. Smith, R. M. Potter, and M. Aven (Abstract No. 65)

3:15 P.M.—"Electroluminescence Maintenance" by W. A. Thornton (Abstract No. 66)

3:40 P.M.—"Effects of Interaction among Particles in Electroluminescent Layers" by A. T. Halpin and Paul Goldberg (Abstract No. 67)

4:00 P.M.—"On the Physical Characteristics and Chemical Composition of Electroluminescent Phosphors" by Paul Goldberg and Sixdenial Faria (Abstract No. 68)

4:20 P.M.—"Detection of Ionization of Eu^{++} in the Phosphor SrS-Eu, Sm by the Paramagnetic Resonance Absorption Method" by V. V. Antonov-Romanovsky, V. G. Dubinin, A.M. Prokhorov, Z. A. Trapeznikova, and M. V. Fock (Abstract No. 68A)

5:00 P.M.—Palladium Medal Address by A. N. Frumkin in the Illinois Room, Mezzanine.

Electronics—Luminescence (cont'd)
Wednesday, May 4, 1960
with Paul Goldberg presiding
(LINCOLN-DOUGLAS ROOMS, 18th floor)

9:00 A.M.—"Copper-Chloride Relationships in Photoluminescent and Electroluminescent Zinc Sulfide Phosphors" by A. L. Solomon and P. Goldberg (Abstract No. 69)

9:25 A.M.—"Effect of CdS on the Electroluminescence of ZnS:Cu Halide Phosphors" by Arthur Dreeben (Abstract No. 70)

9:50 A.M.—"ZnS:Cu, Cl and (Zn, Cd)S:Cu, Cl Electroluminescent Phosphors" by A. Wachtel (Abstract No. 71)

10:15 A.M.—"(Zn, Hg)S and (Zn, Cd, Hg)S Electroluminescent Phosphors" by A. Wachtel (Abstract No. 72)

10.40 A.M.—"Influence of Mg and Cd on the Electroluminescence of ZnS:Cu Phosphors" by P. M. Jaffe (Abstract No. 73)

11:05 A.M.—"Influence of Halogen-Coactivator on the Electroluminescence of ZnS:Cu Phosphors, I. Green Emission" by P. M. Jaffe (Abstract No. 74)

11:30 A.M.—"Electroluminescent Time Average Light Output of a ZnS:Se Phosphor" by J. Mudar, S. Nudelman, and K. Kamyszek (Abstract No. 75)

12:15 P.M.—Electronics Division Luncheon and Business Meeting in the Chicago Room, Mezzanine.

Electronics—Luminescence (cont'd)
Wednesday, May 4, 1960
with F. E. Williams presiding
(LINCOLN-DOUGLAS ROOMS, 18th floor)

2:00 P.M.—"Temperature-Induced Color Shifts in Electroluminescence" by L. W. Strock (Abstract No. 76)

2:20 P.M.—"On the Role of a Stimulating Action of Exciting Light in the Luminescence Kinetics of the Crystalline Phosphor ZnS-Cu" by L. A. Vinokurov and M. V. Fock (Abstract No. 77)

2:45 P.M.—"On the Valency States of Manganese in Phosphor Systems" by V. V. Osiko (Abstract No. 77A)

3:10 P.M.—"Physical Processes in Alkali Halide Phosphors Activated by Mercury-Like Ions" by Ch. B. Lushchik, I. W. Jaek, G. G. Lüdja, N. E. Lushchik, and K. K. Schwarz (Abstract No. 77B)

3:30-4:30 P.M.—Round-table discussion with F. E. Williams, moderator

ELECTRONICS—SEMICONDUCTORS

Monday, May 2, 1960
Crystal Growth
with F. H. Horn presiding
(GRAND BALLROOM, 19th floor)

9:15 A.M.—"An Apparatus for the Preparation of Semiconductor Grade Silicon" by R. C. Ellis, Jr. (Abstract No. 78)

9:35 A.M.—"Twin Generation and Seeding Mechanism in Dendritic Growth" by J. W. Faust, Jr., and H. F. John (Abstract No. 79)

9:55 A.M.—"Propagation of Germanium Dendrites" by R. G. Seidensticker and D. R. Hamilton (Abstract No. 80)

10:15 A.M.—"Some Aspects of Lateral Growth in Dendrites" by H. F. John and J. W. Faust, Jr. (Abstract No. 81)

10:35 A.M.—"Dendritic Growth Studies by Pulse Plating Techniques" by R. C. Smith (Abstract No. 82)

10:55 A.M.—"Growth of Atomically Flat Surfaces on Germanium Dendrites" by A. I. Bennett, R. L. Longini, and W. J. Smith (Abstract No. 83)

11:10 A.M.—"Dendritic Growth of Indium Antimonide" by J. W. Faust, Jr., H. Nicholson, and R. Moss (Abstract No. 84)

11:25 A.M.—"Preparation of Highly Arsenic-Doped Germanium" by P. L. Moody and A. J. Strauss (Abstract No. 85)

11:45 A.M.—Recent News Papers. Titles and short abstracts will be available at the Registration Desk.

Electronics—Semiconductors (cont'd)
Monday, May 2, 1960
Physical Chemistry of Semiconductors
with C. D. Thurmond presiding

(GRAND BALLROOM, 19th floor)

2:00 P. M.—"Crystal Model Studies of Growth Phenomena in III-V Compounds" by R. C. Sangster (Abstract No. 86)

2:25 P.M.—"Orientation Dependent Distribution Coefficients of Tellurium in Indium Antimonide Crystals" by J. B. Mullin (Abstract No. 87)

2:45 P.M.—"Anisotropic Segregation in InSb" by W. P. Allred and R. K. Willardson (Abstract No. 88)

3:05 P.M.—"Study of Copper Precipitation in Silicon Single Crystals" by G. H. Schwuttke (Abstract No. 89)

3:25 P.M.—"Reactions of Oxygen in Ge" by C. S. Fuller, C. D. Thurmond, and W. Kaiser (Abstract No. 90)

3:55 P.M.—"Preparation and Properties of Pseudo-Binary System GaAs-AlAs" by E. P. Stambaugh, J. I. Genco, and R. C. Himes (Abstract No. 91)

4:15 P.M.—"Preparation and Properties of the Pseudo-Binary System GaSb-AlSb" by J. F. Miller, H. L. Goering, and R. C. Himes (Abstract No. 92)

4:45 P.M.—"Phase Diagram for the Binary System Cadmium-Tellurium" by D. R. Mason and B. M. Kulwicki (Abstract No. 93)

5:05 P.M.—Recent News Papers. Titles and short abstracts will be available at the Registration Desk.

Electronics—Semiconductors (cont'd)
Tuesday, May 3, 1960
Compound Semiconductors
with F. D. Rosi presiding

(GRAND BALLROOM, 19th floor)

9:00 A.M.—"Effect of Inhomogeneities on the Hall Coefficient in InSb" by R. T. Bate (Abstract No. 94)

9:20 A.M.—"Properties of P-Type GaAs Prepared by Copper Diffusion" by F. D. Rosi, D. Meyerhofer, and R. V. Jensen (Abstract No. 95)

9:40 A.M.—"Preparation and Properties of ZnSb" by R. C. Bourke, R. Simon, and E. H. Lougher (Abstract No. 96)

10:00 A.M.—"Preparation and Properties of Gallium Phosphide" by C. J. Frosch, M. Gershenzon, and D. F. Gibbs (Abstract No. 97)

10:35 A.M.—"Preparation and Characteristics of P-N Junctions in Gallium Phosphide" by M. Gershenzon and R. M. Mikulyak (Abstract No. 98)

11:00 A.M.—"Preparation and Properties of Grown P-N Junctions of InSb" by H. C. Gorton and F. J. Reid (Abstract No. 99)

11:25 A.M.—"Influence of Crystal Size on the Spectral Response of Evaporated PbTe and PbSe Photoconductive Cells" by W. D. Lawson, A. S. Young, and F. A. Smith (Abstract No. 100)

11:50 A.M.—Recent News Papers. Titles and short abstracts will be available at the Registration Desk.

12:15 P. M.—Society Luncheon and Business Meeting in the Illinois Room, Mezzanine. Bill Veeck, President of the American League Champion White Sox, is guest speaker.

Electronics—Semiconductors (cont'd)
Tuesday, May 3, 1960
Surfaces; Oxide Films
with H. C. Gatos presiding

(GRAND BALLROOM, 19th floor)

2:00 P.M.—"On the Mechanism of Chemically Etching Germanium and Silicon" by D. R. Turner (Abstract No. 101)

2:30 P.M.—Recent News Papers. Titles and short abstracts will be available at the Registration Desk.

3:10 P.M.—"Experimental Micro-etch Techniques on Millimeter Wave-length Diodes" by D. G. Langlais (Abstract No. 102)

3:40 P.M.—"Oxide Masking of Solid SiO_2 against Boron" by Frank Keywell and Marshall Nechtow (Abstract No. 103)

4:00 P.M.—"Oxidation-Induced Diffusion in Silicon" by H. W. Cooper, E. I. Doucette, and R. A. Mehnert (Abstract No. 104)

5:00 P.M.—Palladium Medal Address by A. N. Frumkin in the Illinois Room, Mezzanine.

Electronics—Semiconductors (cont'd)
Wednesday, May 4, 1960
Diffusion
with P. H. Keck presiding

(GRAND BALLROOM, 19th floor)

9:00 A.M.—"Gaseous Diffusion of Arsenic in Germanium" by Carl Pihl and Kurt Lehovec (Abstract No. 105)

9:20 A.M.—"Open Tube Diffusion of Antimony into Germanium" by A. E. Blakeslee (Abstract No. 106)

9:40 A.M.—"Surface Concentration of Indium in Germanium from Gaseous Diffusion, II" by Karl Busen and Earl Meeks (Abstract No. 107)

10:00 A.M.—"A Diffusion Mask for Germanium" by E. L. Jordan and D. J. Donahue (Abstract No. 108)
10:30 A.M.—"Diffusion of Phosphorus in Silicon" by I. M. Mackintosh (Abstract No. 109)
11:00 A.M.—"Experimental Evidence of Surface Damage and Precipitation in Diffused Silicon" by L. Gerlach and R. Haberecht (Abstract No. 110)
11:20 A.M.—"Precision Lapping, Damage, and Diffusion" by C. J. Spector and T. E. McGahan (Abstract No. 111)
11:40 A.M.—"A New Solution to New Diffusion Equation and a New Application of Analog Solutions" by R. Moore and J. Colburn (Abstract No. 112)
12:15 P.M.—Electronics Division Luncheon and Business Meeting in the Chicago Room, Mezzanine.

Electronics—Semiconductors (cont'd)
Wednesday, May 4, 1960
Device Technology
with W. F. Leverton presiding

(GRAND BALLROOM, 19th floor)

2:00 P.M.—"Localized Breakdown in Diffused Silicon Junctions" by B. D. James and P. S. Flint (Abstract No. 113)
2:20 P.M.—Recent News Paper. There is no Abstract No. 114.
2:40 P.M.—"Production of a Germanium PNPN Switching Transistor by Post-Alloy Diffusion" by Fred Barson and John Gow (Abstract No. 115)
3:00 P. M.—"A High-Frequency PNP Diffused Silicon Transistor Produced by the Oxide Masking Technique" by O. Stavik (Abstract No. 116)
3:25 P. M.—Recent News Paper. There is no Abstract No. 117.
3:45 P.M.—"Physical Metallurgy in Semiconductor Device Fabrication, I. Gold Electrode Attachments to Silicon and Germanium" by L. Bernstein, B. G. Bender, and W. B. Warren (Abstract No. 118)
4:05 P.M.—"Physical Metallurgy in Semiconductor Device Fabrication, II. Studies of Gold-Aluminum and Gold-Tin in Electrode Attachment" by L. Bernstein, W. B. Warren, and B. G. Bender (Abstract No. 119)
4:25 P.M.—"Effects of High Aluminum Concentration in Emitters of Germanium Alloyed Power Transistors" by H. K. Becherer and Ernest Paskell (Abstract No. 120)

ELECTROTHERMICS AND METALLURGY

Monday, May 2, 1960
High-Purity Vanadium, Its Preparation, Properties, and Alloys
with D. J. Hansen presiding

(CHICAGO ROOM, Mezzanine)

9:15 A.M.—Introductory remarks by D. J. Hansen

9:20 A.M.—"Resources of Vanadium Minerals—Domestic and Foreign" by Staff Member of the Colorado School of Mines Research Foundation (Abstract No. 121)

9:50 A.M.—"Mining and Beneficiation of Vanadium Minerals" by Staff Member of the Colorado School of Mines Research Foundation (Abstract No. 122)

10:25 A.M.—"Mineralogy and Geochemistry of Vanadium in the Colorado Plateau" by A. D. Weeks (Abstract No. 123)

10:35 A.M.—"Vanadium by Metallic Reduction of Vanadium Trichloride" by M. J. Ferrante and F. E. Block (Abstract No. 124)

11:25 A.M.—"Electrorefining of Vanadium" by D. H. Baker, Jr., and F. R. Cattoir (Abstract No. 125)

Electrothermics and Metallurgy (cont'd)
Monday, May 2, 1960
High-Purity Vanadium, Its Preparation, Properties, and Alloys (cont'd)
with M. Schussler presiding

(CHICAGO ROOM, Mezzanine)

1:30 P.M.—"Preparation of High-Purity Vanadium Metal by the Iodide Refining Process" by O. N. Carlson and C. V. Owen (Abstract No. 126)

1:55 P.M.—"Consolidation and Fabrication of Vanadium" by T. W. Merrill (Abstract No. 127)

2:20 P.M.—"Mechanical Properties of Unalloyed Vanadium" by J. W. Farrell (Abstract No. 128)

2:45 P.M.—"Lattice Parameter and Expansion Coefficient of Vanadium" by W. J. James and M. E. Straumanis (Abstract No. 129)

3:15 P.M.—"Corrosion Properties of High-Purity Vanadium" by David Schlain and C. B. Kenahan (Abstract No. 129A)

3:40 P.M.—"On the Constitution of Some Vanadium-Base Binary and Ternary Systems and the Aging Characteristics of Selected Ternary Alloys" by S. Komjathy (Abstract No. 130)

4:05 P.M.—"Development of Improved Vanadium-Base Alloys for High-Temperature Purposes" by B. R. Rajala and R. J. Van Thyne (Abstract No. 131)

4:30 P.M.—"Properties of Vanadium-Base Alloys" by S. T. Wlodek (Abstract No. 132)

Electrothermics and Metallurgy (cont'd)
Tuesday, May 3, 1960
Methods of Reducing Iron Ores
with John Convey presiding

(ILLINOIS ROOM, Mezzanine)

8:30 A.M.—Introductory remarks by E. M. Sherwood

8:35 A.M.—"Canada's Interest in Methods of Reducing Iron Ores" by John Convey (Abstract No. 133)

9:05 A.M.—"Economic and Process Factors Affecting the Selection of a Direct Reduction Process" by D. C. Brown (Abstract No. 134)

9:35 A.M.—"Solid Fuels and Reductants for the Beneficiation and Reduction of Iron Ores" by H. U. Ross (Abstract No. 135)
10:10 A.M.—"Gas Reactions in Reduction Processes" by J. Huebler (Abstract No. 136)
10:40 A.M.—"Magnetizing Roasting" by D. J. Hains (Abstract No. 137)
11:10 A.M.—Discussion of papers.

Electrothermics and Metallurgy (cont'd)
Tuesday, May 3, 1960
Methods of Reducing Iron Ores (cont'd)
with B. S. Old presiding

(ILLINOIS ROOM, Mezzanine)

2:45 P.M.—"How Are the Blast Furnaces Doing?" by O. R. Rice (Abstract No. 138)
3:15 P.M.—"Performance of the First Commercial H-Iron Reduction Plant" by H. H. Stotler and R. A. Lubker (Abstract No. 139)
3:50 P.M.—"The Nu-Iron Process—A Fluidized Bed Process for Reducing Iron Ore" by T. F. Reed, J. C. Agarwal, and E. H. Shipley (Abstract No. 140)
4:20 P.M.—Discussion of papers.
5:00 P.M.—Palladium Medal Address by J. N. Frumkin in the Illinois Room, Mezzanine

Electrothermics and Metallurgy (cont'd)
Wednesday, May 4, 1960
Methods of Reducing Iron Ores (cont'd)
with R. B. Mears presiding

(ILLINOIS ROOM, Mezzanine)

9:30 A.M.—"Direct Reduction of Fine Iron Ore Concentrates in a Self-Agglomerating Fluidized Bed" by F. M. Stephens, Jr., and B. G. Langston (Abstract No. 141)
10:00 A.M.—"The Esso Research-Little Process" by R. W. Hyde (Abstract No. 142)
10:35 A.M.—"Present Direct Reduction Research at Stora Kopparberg, Sweden" by T. O. Dormsjo (Abstract No. 143)
11:05 A.M.—"The R-N Process" by J. S. Breitenstein (Abstract No. 144)
11:35 A.M.—Discussion of papers.
12:30 P.M.—Electrothermics and Metallurgy Division Luncheon and Business Meeting in Parlor E, Mezzanine.

Electrothermics and Metallurgy (cont'd)
Wednesday, May 4, 1960
Methods of Reducing Iron Ores (cont'd)
with A. C. Haskell presiding

(ILLINOIS ROOM, Mezzanine)

2:00 P.M.—"Reasons for the Co-Current Kiln in Direct Reduction" by Horace Freeman (Abstract No. 145)

2:30 P.M.—"Allis-Chalmers Agglomeration-Reduction Process" by T. G. Kirkland, C. L. Sollenberger, and J. Platner (Abstract No. 146)
3:00 P.M.—"Direct Reduction Research at IRSID" by J. Astier (Abstract No. 147)
3:35 P.M.—"The Jet Smelting Process" by R. L. Cavanagh (Abstract No. 148)
4:05 P.M.—"Electric Smelting and Melting" by H. Walde (Abstract No. 149)
4:35 P.M.—Discussion of papers.

Electrothermics and Metallurgy (cont'd)
Thursday, May 5, 1960
Methods of Reducing Iron Ores (cont'd)
with C. L. Mantell presiding

(ILLINOIS ROOM, Mezzanine)

9:30 A.M.—"Consideration of Fuel Requirements for Iron Ore Reduction" by R. Wild (Abstract No. 150)
10:00 A.M.—"Strategic-Udy Process for Smelting Iron Ores" by M. C. Udy (Abstract No. 151)
10:35 A.M.—"Technical and Economic Factors to Be Considered in the Electric Furnace Reduction of Iron Ores" by N. H. Keyser (Abstract No. 152)
11:05 A.M.—"Electric Smelting of Iron Ores" by F. C. Collin (Abstract No. 153)
11:35 A.M.—Discussion of papers.

Electrothermics and Metallurgy (cont'd)
Thursday, May 5, 1960
Methods of Reducing Iron Ores (cont'd)
with W. M. Armstrong presiding

(ILLINOIS ROOM, Mezzanine)

2:00-4:00 P.M.—General discussion of methods of reducing iron ores (questions and answers, discussion and remarks from the floor). Summary of the conference by W. M. Armstrong.

Electrothermics and Metallurgy (cont'd)
Tuesday, May 3, 1960
Rhenium
with B. W. Gonser and B. J. Clemmer presiding

(PRESS GALLERY, 18th floor)

9:00 A.M.—Introductory remarks by B. W. Gonser
9:05 A.M.—"Mineralogical and Geological Occurrence of Rhenium" by S. R. Zimmerley (Abstract No. 154)
9:30 A.M.—"A Survey of the Different Methods for the Determination of Rhenium" by Suzanne Tribalat (Abstract No. 155)
9:55 A.M.—"Spectrophotometric Determination of Microgram Quantities of Rhenium by E. E. Malouf and R. J. Heaney (Abstract No. 156)
10:25 A.M.—"Some Recent Developments in the Halide and Ditertiary Arsine Chemistry of Rhenium" by J. E. Fergusson and R. S. Nyholm (Abstract No. 157)
10:50 A.M.—"Spectrochemical Analysis of Rhenium Metal Powder" by J. H. Allwein (Abstract No. 158)

11:15 A.M.—"The Crystal Chemistry of the Compounds of Rhenium with Transition Metals" by N. V. Ageev and V. Sh. Shehtman (Abstract No. 159)

12:15 P.M.—Society Luncheon and Business Meeting in the Illinois Room, Mezzanine. Bill Veeck, President of the American League Champion Chicago White Sox, is guest speaker.

Electrothermics and Metallurgy (cont'd)
Tuesday, May 3, 1960
Rhenium (cont'd)
with Chester Sims and A. D. Melaven presiding

(PRESS GALLERY, 18th floor)

2:00 P.M.—"Metallurgical Processes for Recovery of Rhenium from Flue Dusts and Gases" by E. E. Malouf, J. D. Prater, and S. R. Zimmerley (Abstract No. 160)

2:25 P.M.—"Process for Producing Pure Rhenium and Its Compounds" by Marie-Louise Jungfleisch and Henri Ruff (Abstract No. 161)

2:50 P.M.—"Rhenium Powder Metallurgy and Fabrication of Wrought Products" by J. H. Port (Abstract No. 162)

3:20 P.M.—"Behavior of Rhenium during Hot-Working" by Guy Lebert (Abstract No. 163)

3:45 P.M.—"Powder Metallurgy of Refractory Alloys Containing Rhenium" by Marie-Louise Jungfleisch and Jean Fabry (Abstract No. 164)

Electrothermics and Metallurgy (cont'd)
Wednesday, May 4, 1960
Rhenium (cont'd)
with R. I. Jaffee presiding

(PRESS GALLERY, 18th floor)

9:15 A.M.—"Certain Physical Properties of Rhenium and Its Alloys" by E. M. Savitski and M. A. Tylkina (Abstract No. 165)

9:40 A.M.—"Rhenium and Transition Metals Phase Diagrams" by E. M. Savitski and M. A. Tylkina (Abstract No. 166)

10:05 A.M.—"Deformation Characteristics of Rhenium Single Crystals" by G. A. Geach, R. A. Jeffery, and E. Smith (Abstract No. 167)

10:35 A.M.—"The Workability and Mechanical Properties of Tungsten- and Molybdenum-Base Alloys Containing Rhenium" by D. J. Maykuth, F. C. Holden, and R. I. Jaffee (Abstract No. 168)

11:00 A.M.—"Evaluation of Rhenium as an Electrical Contact Material" by V. E. Heil, T. C. Murphy, and L. F. Neely (Abstract No. 169)

12:30 P.M.—Electrothermics and Metallurgy Division Luncheon and Business Meeting in Parlor E, Mezzanine.

Electrothermics and Metallurgy (cont'd)
Wednesday, May 4, 1960
Rhenium (cont'd)
with J. H. Port presiding

(PRESS GALLERY, 18th floor)

2:00 P.M.—"Thermocouples for 3000°C Using Rhenium Alloys" by J. C. Lachman and J. A. McGurty (Abstract No. 170)

2:25 P.M.—"Rhenium in Electronics" by G. B. Gaines (Abstract No. 171)

2:50 P.M.—"Catalytic Hydrogenation of Sulfuretted Organic Compounds in the Presence of Rhenium Heptasulfide" by Constantin Aretos and Jean Vialle (Abstract No. 172)

3:20 P.M.—"On the Use of Pure or Alloyed Rhenium in Oxide Coated Cathodes" by M. P. Warin (Abstract No. 173)

3:45 P.M.—"Electroplating of Rhenium by G. S. Root and John Beach (Abstract No. 174)

Electrothermics and Metallurgy (cont'd)
Thursday, May 5, 1960
Refractory and Reactive Metals
with E. M. Sherwood presiding

(PRESS GALLERY, 18th floor)

9:30 A.M.—"Adhesion of Vapor Deposited Molybdenum Coatings'" by S. T. Wlodek and John Wulff (Abstract No. 175)

10:00 A.M.—"Kinetics of the Oxidation of Pure Tungsten from 500° to 1300°C" by E. A. Gulbransen and K. F. Andrew (Abstract No. 176)

10:30 A.M.—"Preparation and Refining of Yttrium Metal by Y-Mg Intermediate Alloy Process" by O. N. Carlson, J. A. Haefling, F. A. Schmidt, and F. H. Spedding (Abstract No. 177)

INDUSTRIAL ELECTROLYTIC

Monday, May 2, 1960
General Session
with W. D. Sherrow presiding

(ILLINOIS ROOM, Mezzanine)

10:00 A.M.—Introductory remarks by J. C. Cole

10:05 A.M.—"Graphite Anodes in Brine Electrolysis, IV. Effect of Anolyte pH on Corrosion Rate in Chlor-Alkali Cells" by L. E. Vaaler (Abstract No. 178)

10:30 A.M.—"Chemical Engineering Studies on the Decomposition Packed Tower of the Amalgam on the Chlorine-Caustic Industry" by Shinzo Okada, Shiro Yoshizawa, and Fumio Hine (Abstract No. 179)

11:00 A.M.—"A Small-Scale Electro-Organic Chemical Plant" by J. W. Drew and G. J. Moll (Abstract No. 180)

11:30 A.M.—"Intermediate Temperature Fuel Cells" by G. V. Elmore and H. A. Tanner (Abstract No. 181)

12:30 P.M.—Industrial Electrolytic Division Luncheon and Business Meeting in the Illinois Room, Mezzanine. Presentation of the Annual Chlor-Alkali Report by C. A. Hampel and N. J. Ehlers.

Industrial Electrolytic (cont'd)
Monday, May 2, 1960
General Session (cont'd)
with N. J. Ehlers presiding

(ILLINOIS ROOM, Mezzanine)

2:45 P.M.—"Electrolytic Reduction of Thorium Oxide" by L. H. Meyer (Abstract No. 182)
3:15 P.M.—"Metal Mists and Aluminum Losses in the Hall Process" by W. E. Haupin (Abstract No. 183)
3:45 P.M.—"Preparation of Boron from Boron Carbide" by D. R. Stern (Abstract No. 184)
4:15 P.M.—"Lead Dioxide Anode in the Preparation of Perchlorates" by K. C. Narasimham, S. Sundararajan, and H. V. K. Udupa (Abstract No. 185)

THEORETICAL ELECTROCHEMISTRY—INDUSTRIAL ELECTROLYTIC

Joint Symposium
Tuesday, May 3, 1960
Electrochemical Engineering
Applied Electrode Kinetics
with C. W. Tobias presiding

(CENTURY ROOM, 19th floor)

9:15 A.M.—Introductory remarks by C. W. Tobias
9:30 A.M.—"The Measurement of Polarization" by Ernest Yeager (Abstract No. 186)
10:20 A.M.—"Applied Electrochemical Kinetics" by Paul Delahay (Abstract No. 187)
11:10 A.M.—"Electrocrystallization and Surface Films" by D. A. Vermilyea (Abstract No. 188)

Theoretical Electrochemistry—Industrial Electrolytic (cont'd)
Joint Symposium
Tuesday, May 3, 1960
Electrochemical Engineering (cont'd)
Transport Processes in Electrolytic Cells
with Ralph Roberts presiding

(CENTURY ROOM, 19th floor)

2:00 P.M.—"Mass Transport in Electrolysis, Hydrodynamic Factors" by Norbert Ibl (Abstract No. 189)
2:50 P.M.—"Heat Transport and Temperature Distribution in Cells" by T. R. Beck (Abstract No. 190)
3:40 P.M.—Panel discussion, C. W. Tobias presiding. Members of the panel: Sidney Barnartt, J. V. Petrocelli, and B. E. Conway.
5:00 P.M.—Palladium Medal Address by A. N. Frumkin in the Illinois Room, Mezzanine.

Theoretical Electrochemistry—Industrial Electrolytic (cont'd)
Joint Symposium
Wednesday, May 4, 1960
Electrochemical Engineering (cont'd)
Distribution of Potential and Current in Electrolytic Cells
with R. F. Bechtold presiding

(CENTURY ROOM, 19th floor)

9:30 A.M.—"Effect of Geometry on Current Distribution in Industrial Electrolytic Cells" by Scott Lynn and C. W. Tobias (Abstract No. 191)
10:20 A.M.—"Effect of Nongeometric Factors on Current Distribution" by E. A. Grens and C. W. Tobias (Abstract No. 192)
11:10 A.M.—"Electrode Materials and Materials of Construction" by M. S. Kircher and J. E. Currey (Abstract No. 193)

Theoretical Electrochemistry—Industrial Electrolytic (Cont'd)
Joint Symposium
Wednesday, May 4, 1960
Electrochemical Engineering (cont'd)
Scale Up and Measurements on the Plant Scale
with J. C. Cole presiding

(CENTURY ROOM, 19th floor)

2:00 P.M.—"The Problem of Scale Up of Electrolytic Processes" by R. B. MacMullin (Abstract No. 194)
2:50 P.M.—"Measurements on a Plant Scale" by C. J. Dobratz (Abstract No. 195)
3:40 P.M.—Panel discussion, R. F. Bechtold presiding. Members of the panel: Norbert Ibl, N. J. Johnson, and R. B. MacMullin.

THEORETICAL ELECTROCHEMISTRY

Thursday, May 5, 1960
with L. G. Longsworth presiding

(LINCOLN-DOUGLAS ROOM, 18th floor)

9:00 A.M.—"Double Layer Structure and Relaxation Methods for Fast Electrode Processes" by Hiroaki Matsuda and Paul Delahay (Abstract No. 196)
9:20 A.M.—"The Interpretation of Measurements of Potential Decay on Open Circuit" by P. C. Milner (Abstract No. 197)
9:40 A.M.—"Cathodic Processes on Passive Zirconium" by R. E. Meyer (Abstract No. 198)
10:00 A.M.—"Kinetics of Anodic Processes in Carboxylic Acids" by B. E. Conway and M. Dzieciuch (Abstract No. 199)
10:20 A.M.—"Faradaic Rectification with Control of Alternating Potential Variations—Application to Electrode Kinetics for Fast Processes" by Hiroaki Matsuda and Paul Delahay (Abstract No. 200)
10:40 A.M.—"The Influence of Cations on the Differential Capacity of the Mercury Dropping Electrode in Methanol and Ethanol Solutions of Electrolytes" by S. Minc (Abstract No. 201)

11:00 A.M.—"Irreversible Thermodynamics in Electrochemistry" by A. J. deBethune (Abstract No. 202)

11:30 A.M.—Theoretical Electrochemistry Division Business Meeting in the Lincoln-Douglas Rooms, 18th floor.

Theoretical Electrochemistry (cont'd)
Thursday, May 5, 1960
with Paul Delahay presiding

(LINCOLN-DOUGLAS ROOMS, 18th floor)

2:00 P.M.—"Potentials in the System, Cr(II)-Cr(III), at Various Electrodes" by K. B. Morris (Abstract No. 203)

2:20 P.M.—"Electrochemical Study of Metallic Oxides in Fused Lithium Chloride-Potassium Chloride Eutectic" by H. A. Laitinen and B. B. Bhatia (Abstract No. 204)

2:40 P.M.—"Gas-Phase Charged and Electrolytically Charged β-Pd-H Alloys" by J. P. Hoare (Abstract No. 205)

3:00 P.M.—"Kinetics of Cathodic Hydrogen and Deuterium Evolution" by B. E. Conway (Abstract No. 206)

3:20 P.M.—"Behavior of Hydrogen at Oxidized Platinized Platinum Electrodes" by N. J. Ward and T. C. Franklin (Abstract No. 207)

3:40 P.M.—"Transient Strain Induced Electrode Potentials" by Eric Baum, W. F. Seyer, and Ken Nobe (Abstract No. 208)

4:00 P.M.—"Electrocapillary Studies on Solid Metals" by D. N. Staicopoulos (Abstract No. 209)

4:20 P.M.—"A New Model for Evaluating the Conductivities of Dispersions" by R. E. Meredith and C. W. Tobias (Abstract No. 210)

Abstracts

ELECTRIC INSULATION

Abstract No. 1

Electrolytic Oxide Films

J. Burnham, 10960 Verano Drive, Los Angeles 24, Calif.

The nature of the dielectric film in electrolytic capacitors has been a subject of continuing interest over the past fifty years and it is a surprising thing that not more is known about the nature of these films, their chemical and physical properties, or their mechanism of formation.

The increasing economic importance of other metals in the electrolytic capacitor field has renewed interest in the fundamental properties of anodic oxides and a considerable amount of recent work covers the determination of thickness, dielectric constant and electrical resistivity.

The advent of the diode-capacitor with voltage sensitive properties and the solid electrolytic capacitor

developed by the Bell Laboratories has increased interest in the interface which is the seat of the dielectric and it appears that we are dealing in both cases with a p-n junction whose properties are not yet well understood. Recent work in the above areas is discussed.

Abstract No. 2

Conduction, Storage, and Photoelectric Phenomena in Anodic Aluminum Oxide Films

Kurt Lehovec, Sprague Electric Co., North Adams, Mass.

The paper covers unpublished work by Dr. Hans Reinheimmer, Alma Marcus, and the author. We have studied the d-c current voltage characteristic of anodically polarized aluminum oxide films sandwiched between aluminum and an electrolyte. The well-known pronounced polarization effects have been observed and the time dependence of polarization has been analyzed, using a theoretical model based on trapping centers in the oxide film. When the applied voltage is removed after a certain time of application and the anodic film is short circuited externally, it is found that an electric current flows in the external circuit which decreases approximately inversely with time over periods of many hours, and this dependence is analyzed theoretically. Illumination during this discharge period changes the discharge current and the spectral distribution of this photo effect is discussed. Results of certain measurements are also discussed.

Abstract No. 3

Impedance Characteristics of Anodic Oxides

L. Young, British Columbia Research Council, University of British Columbia, Vancouver 8, B.C., Canada

Impedance characteristics of anodic oxide films are determined by several factors which are somewhat difficult to disentangle. These are as follows: (A) Dielectric properties of the oxide material as expressed by dielectric constant and tan δ (or in alternative notation by real and imaginary dielectric constants). The dielectric losses at low frequencies are probably due largely to ionic relaxation processes which, of course, also contribute to the dielectric constant. (B) Weak places, such as fissures, pores, or local areas of conducting oxide, provide leakage circuit-elements in parallel with the film proper. (C) Interfacial effects, including electrical double layer effects at the oxide solution interface. (D) Effects due to d-c electronic conductivity of part or all of the film. A review is given of these factors and the degree to which they allow the complicated data in the literature to be explained.

Abstract No. 4

Tantalum Anode Reactions

Donald Stephenson and **Robert Russ,** Transitor Electronics, Inc., Bennington, Vt.

When tantalum is made the anode in an electrolytic cell and voltage applied, several reactions can take place. The result of these chemical reactions may be an etch, a polish, or polarization of the tantalum resulting in anodic oxidation. The variables which control these reactions may be the choice of electrolyte, or it may be current density, temperature, electrode position, and many others. An attempt to summarize and explain these effects is made.

Abstract No. 5

Dielectric Characteristics of Tantalum Anodic Oxide Films As Related to Film Structure

D. Mohler, Capacitor Dept., General Electric Co., Hudson Falls, N. Y.

The variation of the dielectric characteristics of tantalum anodic films cannot be explained on the basis of bulk metal impurities alone. The thin air oxide film on tantalum determines the structural properties of anodic films formed thereon. The dielectric characteristics in turn, are related to the physical and chemical structure of the film. Electron diffraction and spectrographic data support this view.

Abstract No. 6

Hydrated Oxide Films on Aluminum

Dietrich Altenpohl, Aluminum-Walzwerke Singen, Singen/Hohentwiel, West Germany

Hydrated oxide films on aluminum are of importance for the corrosion protection of aluminum in contact with water solutions or in contact with atmosphere. The growth of hydrated oxide on aluminum surfaces depends on temperature and time of interaction between aluminum and H_2O, but also on the interaction with small impurities in the water or in the metal. Hydrated oxide films are of importance for the dielectric properties of electrolytic capacitors, and corresponding investigations are described.

Abstract No. 7

Anodic Formation of Aluminum Oxide Films, I. The Influence of Surface Preparation on Film Properties

W. E. Tragert and **J. R. Rairden,** Research Lab., General Electric Co., Schenectady, N. Y.

It is shown that the effect of various surface cleaning agents on anodizing behavior is attributable to the

complexing action of specific anions with the residual hydrous alumina surface film. The effectiveness of matrix films formed prior to anodizing is shown to depend on the chemical as well as electrical conditions of their formation. A generalization is drawn between the ultimate dielectric properties of anodic films and the prior chemical and electrolytic treatment of the aluminum.

Abstract No. 8

Anodic Formation of Aluminum Oxide Films, II. Effect of Various Electrical Forming Conditions on Film Properties

W. E. Tragert and **J. R. Rairden,** Research Lab., General Electric Co., Schenectady, N. Y.

The two principal anodic film forming techniques, constant current and constant voltage, are examined with respect to the resultant structure and composition of the films. It is shown that the ultimate electrical properties of the film can be related to composition and hence to forming technique. The influence of reverse polarization is discussed. The effect of electrolyte composition on film structure and composition is considered.

Abstract No. 9

Determination of the Thickness of Thin Porous Oxide Films on Aluminum

M. S. Hunter and **P. F. Towner,** Aluminum Co. of America, P.O. Box 772, New Kensington, Pa.

A method is described for measuring the thickness of thin porous oxide films on aluminum employing the grazing angle interference colors characteristic of thin transparent films. In conjunction with oxide film step gauges formed under precisely controlled conditions, measurements to about 7Å are possible. Application of the method for measuring film growth in various solutions and in the evaluation of the characteristics of barrier-type electrolytes is also demonstrated.

Abstract No. 10

Capacitor Grade Tantalum

L. H. Belz, Kawecki Chemical Co., Boyertown, Pa.

The extraction and refining of tantalum metal is reviewed. The production of high-purity powder and foil is described along with a discussion of the specifications and functional quality of capacitor grade tantalum. Powder types are tabulated and powder characteristics are related to sintered anode design. The production of sintered anodes is also reviewed.

Abstract No. 11

Measurement of the Specific Surface Area of Tantalum Powders and Sintered Anodes

W. G. Guldner and **C. C. Houtz**, Bell Telephone Labs., Murray Hill, N. J.

In the production of porous anodes for electrolytic capacitors, the anodes are prepared by compressing and sintering tantalum powder. Since the capacitance of the anodes as used in capacitors is proportional to their surface area, this study was initiated to measure the surface areas of powders obtained from various suppliers and of sintered pellets prepared from these powders. The data show the loss in surface area for different powders as a result of sintering. Also, a comparison is shown of the specific surface area of pellets obtained by gas adsorption with that area calculated from capacitance measurements. Specific surface areas were measured by the Brunauer, Emmett, and Teller method using krypton at liquid nitrogen temperature.

Abstract No. 12

Some Physical Properties of Metallic Tantalum

J. I. Budnick, IBM Research Lab., Poughkeepsie, N. Y.

Studies of the purification of tantalum metal are described with emphasis on the usefulness of measurements of the superconducting properties as a powerful tool for evaluating sample perfection. Very small amounts of gaseous impurities have pronounced effects on the superconducting properties. The nuclear magnetic resonance absorption, which for tantalum is extremely sensitive to strain and impurities, has been observed in metal foil.

Abstract No. 13

Low-Temperature Sintering of Tantalum Anodes

C. J. B. Fincham and **G. J. Villani**, Metals Div., National Research Corp., Cambridge, Mass.

The sintering of tantalum anodes at temperatures lower than those customarily used in the capacitor industry appears to be a promising approach to obtaining substantially higher capacitance per unit weight or volume. Using tantalum powders of differing chemical purities and particle size distributions, a study was made of the chemical and electrical properties of anodes sintered at low temperatures, i.e., down to about 1500°C.

Abstract No. 14

Determination of the Thickness of Anodic Oxide Films by the Spectrophotometric Method in Conjunction with the Abelès Method for the Refractive Index

L. Young and **J. E. Orme,** British Columbia Research Council, University of British Columbia, Vancouver 8, B.C., Canada

The study of anodic oxide films has reached the stage at which the precise determination of the film thickness is required in absolute (as opposed to arbitrary) units. Most of the various methods of determining thickness (Faraday's law, weighing, a-c capacity) require assumptions about the true area and the composition or other properties of the film as well as a knowledge of parameters such as the density or dielectric constant, which may vary with the formation procedure and are not easily determined with sufficient accuracy. The spectrophotometric method gives a rapid and accurate measure of increments of thickness or, if the optical constants of the metal are accurately known, of absolute thickness. A knowledge of the refractive index at one wave length is required, and, if the film is uniform through its thickness, this information may be obtained with good accuracy by the Abelès method. Some applications of these techniques are discussed.

Abstract No. 15

Electrolytic Etching of Dense Tantalum

A. L. Jenny and **R. A. Ruscetta,** Capacitor Dept., General Electric Co., Irmo, S. C.

A practical method of etching dense tantalum for the purpose of magnifying its effective surface area is described. The degree of surface area magnification is related to such parameters as electrolyte composition, anodic current density, temperature, and the characteristics of metal specimens to be treated. The decrease in surface area magnification as a function of post-etch anodizing voltage apparently signifies the filling-in of certain etch pits with tantalum oxide and gives a clue to the size of these pits.

Abstract No. 16

Niobium (Columbium) Solid Electrolytic Capacitors

N. Schwartz, M. Gresh, and **S. Karlik,** Bell Telephone Labs., Inc., Murray Hill, N. J.

Field crystallization of the amorphous niobium oxide film has been found to be a determining factor for the properties of niobium solid electrolytic capacitors. Purity of the porous anodes as dependent on the sintering conditions, formation temperature and voltage, and formation electrolytes, parameters all known to control the initiation of crystallization, have been correlated with the initial and life test properties of these capacitors. The initial properties of niobium solid electrolytic capacitors compare favorably with equivalent tantalum components. However, with the current purity of niobium powder, only units with operating voltages

up to 20 v survive a life test at 85°C, with the failures of capacitors rated at higher voltages attributed to the partial crystallization of the amorphous film during formation.

Abstract No. 17

Columbium (Niobium) Electrolytic Capacitors

A. Shtasel and **H. T. Knight,** Fansteel Metallurgical Corp., North Chicago, Ill.

Columbium metal was evaluated for wet and solid electrolytic capacitors. Anodic oxidation properties were studied in relation to the manufacture of capacitors. The thickness of the oxide films on columbium and tantalum as a function of the forming voltage was compared. The choice of forming and fill electrolytes was found to be more limited with columbium than with tantalum. Solid columbium capacitors with electrical properties comparable to similar tantalum units were operated as high as 35 v. Life tests at 85°C of 10-v wet and solid columbium capacitors were irradiated to a total integrated fast neutron flux of 3.9×10^{16} neutrons /cm^2 without significant damage.

Abstract No. 18

Silicon Nitride Thin Film Dielectric

C. R. Barnes and **C. R. Geesner,** Electronic Technology Lab., Wright Air Development Center, Wright-Patterson Air Force Base, Ohio

Thin adherent nonporous films of pure silicon nitride have been deposited from the vapor phase on hot molybdenum substrates by pyrolytic deposition. Such films, when incorporated between molybdenum plates to form capacitors, were found to maintain satisfactory dielectric properties up to and above 600°C. Silicon nitride coatings deposited by the method herein described also offer a convenient and effective method of encapsulation for protecting metal surfaces from atmospheric oxidation up to and above 1000°C.

Abstract No. 19

Properties of Anodically Formed Oxide Films on Tungsten

H. W. Pitman and **D. C. Hamby,** Linfield Research Institute, McMinnville, Oreg.

Properties of anodically formed oxide films on tungsten have been investigated by coulometric, optical interference, and capacitance methods in the current density range from 0.037 to 8.6 ma/cm^2. The ionic current density in film formation shows an exponential dependence on the field in the film. Properties discussed are the field in the film and current efficiency of film formation as functions of current density, and

the refractive index, optical dispersion, density, and effective dielectric constant.

Abstract No. 20

Ion Size Effect and Mechanism of Electrolytic Rectification

P. F. Schmidt, Westinghouse Research Labs., Pittsburgh 35, Pa., and **F. Huber** and **R. F. Schwarz,** Philco Corp., Philadelphia 34, Pa.

The electron flow through anodic oxide films under cathodic bias has been investigated as a function of cation size. Both the magnitude of the cathodic current and the activation energies for cathodic current flow were found to depend on the size of the cation in solution. Specific adsorption of some cations may exclude other cations from the interface. The existence of a surface barrier of about 1 v and of about 250Å thickness has been proven. The barriers to electron flow inside the oxide and at its interfaces is discussed.

Abstract No. 21

The A-C Properties of Tantalum Solid Electrolytic Capacitors

D. A. McLean, Bell Telephone Labs., Inc., Murray Hill, N. J.

The a-c losses in tantalum solid electrolytic capacitors are of two kinds: those in the dielectric oxide film and those in the manganese oxide semiconductor. By making measurements at two or more suitable frequencies these losses can be separated. The method of separation is described in detail and illustrated with a number of examples. Use of this type of analysis in fundamental studies of materials and processes and in preparation of specifications is discussed. A theoretical treatment of the series losses in the MnO_2 of a cylindrical porous anode is given. A relation between losses in the dielectric and the frequency coefficient of capacitance is illustrated and discussed.

Abstract No. 22

A Mathematical Model for the Porous Type Tantalum Anode Capacitor

J. S. Fisher, Bell Telephone Labs., Inc., Merrimack Valley, Mass.

Reducing the physical size of capacitors while maintaining large values of capacitance can cause their high-frequency behavior to become affected strongly by distributed capacitance and electrode resistance. A good understanding of these effects can generally be acquired by analyzing the capacitor structure with transmission line techniques. The behavior of porous

tantalum anode capacitors has been analyzed by such techniques, showing the effect of the various parameters on their high-frequency performance.

Abstract No. 23

Cathodic Depolarization in Tantalum Electrolytic Capacitors

T. C. O'Nan, P. R. Mallory & Co., Inc., Indianapolis, Ind.

For maximum capacitance and minimum internal resistance, the cathode should be nonpolarizable, nonfilming, and nongassing while being substantially inert to the electrolyte. It should respond electrochemically to pulsating (a-c) current—dissolving while anodic and redepositing while cathodic. Commonly employed cathode materials approach this circumstance, but electrochemical activity from a-c balance out, leaving no metal ions in solution. Therefore, d-c leakage currents discharge hydrogen, with attendant gas polarization and pressure increase. Cathodic depolarization minimizes these effects. Certain metal ions, which deposit and redissolve electrochemically at the cathode with high efficiency in preference to hydrogen, may perform successfully, if the deposit is adequately conductive and inert to the electrolyte. Extended depolarization capacity may be supplied through use of the proper form of excess solid material. Soluble "redox systems" may also offer cathodic depolarization. Representative systems are discussed from both theoretical and practical view points.

Abstract No. 24

Cell and Thermoelectric Effects of Tantalum Electrolytic Capacitors

J. M. Law and **W. C. Richards,** Fansteel Metallurgical Corp., North Chicago, Ill.

A voltage is normally present across the terminals of electrically isolated electrolytic tantalum capacitors. The magnitude, cause, and source impedance of this voltage were investigated. Voltages in excess of 1 v were generally due to dielectric hysteresis, or to a charge remaining from previous electrification. Wet-electrolyte units appear to generate a small high-impedance cell emf between the tantalum anode and the silver case. Solid-electrolyte units appear to generate thermoelectrically a small high-impedance emf.

Abstract No. 25

A Selective Electrochemical Etching Procedure to Improve D-C Characteristics of Oxide Film Capacitors

R. W. Berry, N. Schwartz, M. J. Urban (present address: Weston Div., Daystrom Inc., Newark, N. J.), and **M. Gresh,** Bell Telephone Labs., Inc., Murray Hill, N. J.

The d-c leakage of anodic oxide film capacitors is presumed to be associated primarily with discrete defects in the dielectric. After the initial film has been grown by anodizing, an electrochemical etch using a halide in a nonaqueous solvent as the electrolyte removes the underlying anode metal, with its associated impurities, only at defects where appreciable current exists. A more coherent oxide film can then be regrown in a subsequent anodization, and lower d-c leakages result. The paper discusses the application of this technique to tantalum printed capacitors and to aluminum and niobium solid electrolytic capacitors.

Abstract No. 26

Equivalent Series Resistance of Anodically Formed Oxide Films on Aluminum

W. J. Bernard, Electrolytic Capacitor Div., Research and Engineering Dept., Sprague Electric Co., North Adams, Mass.

Measurement of the oxide film contribution to the equivalent series resistance of an electrolytic cell leads to an understanding of the temperature- and frequency-dependent behavior of aluminum electrolytic capacitors. An experimental procedure is described which allows accurate measurements of oxide film resistances. Interpretation and application of the data to the power factor of electrolytic capacitors are given.

Abstract No. 27

Factors Determining Allowable Ripple Current at Various Frequencies in Aluminum Electrolytic Capacitors

R. Lane and **A. Bennett,** Pyramid Electric Co., Darlington, S. C.

The variation in allowable ripple current with changes in frequency for aluminum electrolytic capacitors is discussed. The effects of various materials and processing methods on the ability to operate such capacitors at high values of ripple current are described.

Abstract No. 28

500°C Capacitors

R. J. Stamets and **R. A. West,** Capacitor Dept., General Electric Co., Hudson Falls, N. Y.

Aluminum and tantalum, the conventional electrolytic capacitor anode materials, have serious limitations for use at high temperatures. However, use of a new anode material permits operation of an anodically formed aluminum oxide dielectric in a stacked or wound foil construction at temperatures as high as 500°C (932°F). Capacitance values up to 0.06 μf have been made. In-

sulation resistance values as high as 40 megohm μf at 500°C have been obtained.

Abstract No. 29

A Novel Low Voltage Electrolytic Capacitor without Conventional Spacers

A. J. Catotti and **R. A. West,** Capacitor Dept., General Electric Co., Hudson Falls, N. Y.

Anodization of aluminum in certain acid solutions results in a porous oxide film. Novel low voltage electrolytic capacitors are described which utilize the barrier portion of this aluminum oxide film as the dielectric and the porous portion as the separator. Means of regulating the thicknesses of these two layers are discussed. Electrical characteristics and life test data are presented for a number of voltages and designs.

Abstract No. 30

Volume Resistivity of Ammonium Ethylene Glycoborate Electrolytes

C. C. Houtz, Bell Telephone Labs., Inc., Murray Hill, N. J.

While the ammonium ethylene glycoborates are used commonly as electrolytes in the manufacture of aluminum electrolytic capacitors, little information is available in the literature which relates composition to volume resistivity. Electrolytes were prepared in a range of proportions of ammonium hydroxide, ethylene glycol and boric acid. Resistivities at 1000 cps are shown on ternary diagrams for temperatures of 30° and 85°C. Effects on resistivity are shown for variation in reaction time and temperature and other preparation variables.

Abstract No. 31

Electrical Properties of Some Aliphatic Acids and Alcohols

A. M. Parks, International Business Machine Corp., Yorktown Heights, N. Y.

The dielectric constants and losses of some relatively low molecular weight aliphatic acids and alcohols have been measured in an Elliott cell over a frequency range of 100-100,000 cps and a temperature range of 0°-100°C. The dipole moments have been estimated from measurements on benzene solutions and the volume resistivities calculated from resistance measurements. The effect of monohydroxyl or carboxyl substitution, chain length, and position of substitution as well as the most probable configuration are discussed in terms of these electrical properties.

Abstract No. 32

Effects of Tropical Exposure on the Electrical Properties of Insulating Materials

L. J. Frisco, Dielectrics Lab., The Johns Hopkins University, Baltimore 2, Md.

Measurements of dielectric constant, dissipation factor, d-c surface and volume resistivity, flashover strength, and dielectric strength have been made on specimens which were stored at the Naval Research Laboratory, Tropical Exposure Site, Panama Canal Zone, for periods up to five years. Data are presented to demonstrate the serious degradation exhibited by several materials.

Abstract No. 33

Effect of Heat on the Electrical Properties of Paper

L. H. Wirtz and **T. D. Callinan,** International Business Machine Corp., Research Center, Yorktown Heights, N. Y.

The dielectric constants and dielectric loss factors of handsheets made from Bauer-McNett fractions of semi-bleached sulfate woodpulp were determined over the relative humidity range, 0-92%, and were compared with the electrical properties of similar handsheets which had been subjected to temperatures of 165°C.

Abstract No. 34

The Electric Strength of Insulating Liquids

A. H. Sharbaugh, Research Lab., General Electric Co., Schenectady, N. Y.

The mechanisms of dielectric rupture in liquids are reviewed critically.

Abstract No. 35

Dielectric Properties of Very Thin Films of Liquid Dielectrics

T. Salomon, Institut Francais du Petrole, Paris, France

The production of electrostatic charges in thin films of oils may possibly be explained by the fact that films 10μ thick behave like metallic conductors. This would be in line with the experimental behavior of liquid dielectrics which exhibit changes in dielectric strength and conductivity when tested in small gaps.

ELECTRONICS—GENERAL

Abstract No. 36

Micromodular Solid Tantalum Capacitors

A. W. H. Smith, P. R. Mallory & Co., Inc., 3029 E. Washington St., Indianapolis, Ind.

Solid tantalum capacitors have been made in the geometry required for the Signal Corps Micromodule Development Project. A brief description of the structures made for R.C.A., the prime contractor, is given and also the ratings and sizes currently available. The electrical characteristics of these units are presented and discussed within the frame work of the Signal Corps Requirement SCL-6402A. Evidence of reliability is also presented in the form of load life test data for up to 5000 hr.

Abstract No. 37

Digital Programming Unit for Automatic Temperature Control

N. L. Hozak, J. S. Cook, and **D. R. Mason,** Dept. of Chemical and Metallurgical Engineering, University of Michigan, Ann Arbor, Mich.

A low-cost, compact, flexible, simple, digital, temperature program unit for controlling an electric furnace has been designed and built. The set-point emf for a potentiometer-type temperature controller is derived from a series combination of a chromel-alumel thermocouple in the furnace and an auxiliary emf generator. Each 15 min a stepping switch selector-and-indicator circuit can change the magnitude of the auxiliary emf by a multiple of 25°C and, hence, the effective set point of the controller. Temperature programming is obtained from a patchboard between the emf generator and the selector circuit. The response is limited only by the time constant of the furnace.

Abstract No. 38

An Economical, Automatic, Differential Thermal Analysis System

C. E. Barnes and **D. R. Mason,** Dept. of Chemical and Metallurgical Engineering, University of Michigan, Ann Arbor, Mich.

An automatic differential thermal analysis system is described. A pulse generator, driving a motor-driven autotransformer and electric furnace combination, produces a linear heating rate which can be varied from about 1°C/min to 6°C/min from room temperature to 1200°C. The furnace holds two samples and a reference material inside a nickel block. A dual range recorder with an electrically actuated range switch is used to record the sample temperatures (0-50 mv range) and the differential temperatures between the samples and the reference material (—0.5 to +0.5 mv range). Every 20 sec the pulse generator also actuates a stepping switch which selects the appropriate thermocouple combinations and recorder ranges. Characteristic results and interpretations are presented.

Abstract No. 39

Electroluminescent-Piezoelectric Flat Panel Displays

S. Nudelman, J. Lambe (present address: Scientific Labs, Ford Motor Co., Dearborn, Mich.), **J. Mudar,** and **G. Trytten,** The University of Michigan, Willow Run Labs., Ann Arbor, Mich.

Flat display panels are under development using electroluminescent phosphors on piezoelectric materials. Electroluminescence is stimulated by strong electric fields created at the surfaces of mosaic elements when driven at their piezoelectric resonant frequencies. When all elements are placed in parallel with each resonant at different frequencies, a modulatable light spot can be made to move about in a controlled manner by varying the electrical field strength and frequency applied to the mosaic.

ELECTRONICS—LUMINESCENCE

Abstract No. 40

Phenomenological Theory of Luminescence of Nonphotoconducting Phosphors

Yasuo Uehara, Matsuda Research Labs., Tokyo Shibaura Electric Co., Ltd., Kawasaki, Japan

After a formulation of a fundamental equation of luminescence which can explain various luminescent properties of nonphotoconducting phosphors under excitation by ultraviolet of constant intensity at thermal equilibrium, calculated results of various characteristics of luminescence are compared with experimental results. Furthermore, the theory is extended to the interpretation of the luminescent properties of phosphors under excitation by charged particles.

Abstract No. 41

Irreversible Thermodynamics of Solid-State Luminescence

F. E. Williams, Research Lab., General Electric Co., Schenectady, N. Y.

Solid-state luminescence can be shown to be irreversible. Irreversible thermodynamics provides more severe limitations than does equilibrium thermodynamics. Because the second law must be satisfied locally for irreversible processes, the entropy increase associated with the radiation must balance any entropy decrease accompanying de-excitation. This requirement precludes quite generally injection electroluminescent emission intensities in excess of the electrical input. Irreversible thermodynamics also limits multiply excited antistokes photoluminescence. Common limitations of electro-and photoluminescence are discussed.

Abstract No. 42

Shape of Absorption Bands in Solids

J. J. Markham, Zenith Radio Corp., Chicago, Ill.

The theories of the shape of an optical absorption band in solid are reviewed. The shape is related to the emission and the absorption of phonons. It depends on the temperature of the crystal. The theories are related to the measured absorption bands associated with F centers in KCl and NaCl.

Abstract No. 43

Atomic Wave Functions of Activators

K. H. Butler, Sylvania Lighting Products, 60 Boston St., Salem, Mass.

The *sp* configuration is characteristic of the excited states of many primary activator ions, i.e., Sb^{3+}, Sn^{2+}, Tl^{+}. Quantum mechanical formulas show that the electron density distribution of this configuration depends strongly on the coupling of the electron spins and the magnetic quantum number of the combined electrons. The marked difference in the shapes of an ion in the $^1P_1^o$ and $^3P_1^o$ states, combined with variations in the coordinator number of the surrounding anions in different crystal structures, explains such phenomena as the polarization of luminescence in KCl:Tl and the appearance of two emission bands in many tin-activated phosphors as contrasted to the single emission band for most materials activated by lead or antimony.

Abstract No. 44

The Significance of Measurements of the Temperature Dependence of Luminescence Intensity

C. H. Haake, Research Dept., Westinghouse Electric Corp., Bloomfield, N. J.

The quantum efficiency of a phosphor and its absorptance for the exciting radiation often exhibit opposite temperature trends. The latter may increase while the former decreases, thus producing a luminescence maximum at a certain temperature. Unlike the quantum efficiency the absorptance is a function of various external parameters. Thus the thickness of the phosphor layer drastically influences the shape of a curve of luminescence intensity vs. temperature. Experimental data are presented and discussed.

Abstract No. 45

Absolute Spectral Reflectance of Phosphors

J. E. Eby, Sylvania Lighting Products, 60 Boston St., Salem, Mass.

Absolute measurements of the spectral reflectivity were made on a number of phosphor samples using a modified Beckman DK-1 Spectrophotometer. The

method of making these measurements, which covered the range from 240 μ to 750 μ, is described and data given. These data were then used in conjunction with determinations of particle size distribution to compute the absorption coefficient of the luminescent materials.

Abstract No. 46

Infrared Spectroscopy in Phosphor Research

M. J. B. Thomas and **C. W. Jerome,** Sylvania Lighting Products, 60 Boston St., Salem, Mass.

Use of infrared spectrophotometry as a technique for the identification of compounds has become extremely important with respect to organic compounds and to a somewhat lesser extent with respect to inorganic compounds. There has been, however, no application of this technique to luminescent materials. Infrared studies of the various commercial phosphors and the starting materials used in their manufacture have been made in the 3-15 μ region. The absorption structures of many of the materials are characteristic and may be used in the study of mechanism of phosphor formation.

Abstract No. 47

Factors Influencing Luminescent Emission Studies of the Rare Earth Ions

L. G. Van Uitert, Bell Telephone Labs., Inc., Murray Hill, N. J.

Many of the rare earth ions exhibit fluorescent emission from more than one electronic level when excited. The number of emitting levels depends on the extent to which the f-electrons are perturbed by their surroundings. Increasing the concentration of terbium or europium in calcium tungstate, for example, quenches their high wave number emission states. This probably occurs through the development of exchange coupling between rare earth ions in neighboring calcium sites.

Abstract No. 48

Some Optical Properties of Powder and Crystal Halophosphate Phosphors

P. D. Johnson, Research Lab., General Electric Co., Schenectady, N. Y.

Diffuse reflectivity measurements in the far ultraviolet on halophosphate phosphors show that intrinsic optical absorption by the host lattice begins at about 1500Å in fluoroapatite and 1570Å in chloroapatite. Absorption in bands due to manganese in fluoroapatite at 1600, 1750, and 2150Å results in luminescence in the absence of antimony. Absorption due to antimony lies between 1600 and 2900Å. Optical transmission measure-

ments on synthetic crystal apatite confirm the position of the intrinsic absorption.

Abstract No. 49

Energy Levels of the Antimony Center in Halophosphates

F. E. Williams, Research Lab., General Electric Co., Schenectady, N. Y.

It is recognized that Sb^{+++} substitutes for type II Ca^{++} in halophosphates and simultaneously $O^{=}$ replaces the halogen neighbor. We consider the energy levels of this activator system. The atomic states of Sb^{+++} are similar to those of Tl^{+} which, as an activator, has been studied theoretically. In addition, electron transfer processes can occur in the Sb^{+++} —$O^{=}$ system which may be described as a donor-acceptor pair. Configuration interaction between the atomic and transfer states is considered.

Abstract No. 50

Lead- and Manganese-Activated Calcium-Cadmium Silicate Phosphors

Yasuo Uehara, Yoshimasa Kobuke, Isoo Masuda, and **Takashi Kushida,** Matsuda Research Lab., Tokyo Shibaura Electric Co., Ltd., Kawasaki, Japan

Characteristics of lead- and manganese-activated calcium-cadmium silicate phosphors with various mole ratios of cadmium to calcium were investigated. Two group of phosphors prepared by using cadmium sulfate and carbonate as cadmium raw materials gave different characteristics. They showed different irregular shifts of emission peaks with increasing concentration of cadmium, while a similar linear relation between the lattice spacing and concentration of cadmium was obtained. Observed results are discussed.

Abstract No. 51

Luminescence vs. Composition Studies of Complex Zinc and Cadmium Orthophosphates Containing Sodium and Lithium

A. L. Smith, Electron Tube Div., Radio Corp. of America, Lancaster, Pa.

Zinc or cadmium orthophosphates react with lithium or sodium orthophosphate to form compounds of more or less complex stoichiometry. The manganese-activated luminescences of these compounds have been determined, and an attempt has been made to correlate them with x-ray diffraction studies.

Abstract No. 52

Cadmium Phosphate Phosphors

R. C. Ropp, Chemical & Metallurgical Div., Sylvania Electric Products Inc., Towanda, Pa.

A study of the preparation and properties of both $Cd_2P_2O_7$:Mn (λ max = 618 μ) and $Cd_3(PO_4)_2$:Mn (λ max = 604 μ) revealed that these phosphors become sensitized to 2537A if heated in air or nitrogen to form the matrix followed by reheating in a reducing atmosphere. Excitation data show shifts as a function of both preparation atmosphere and phosphor formulation. Addition of zinc or magnesium gives redder phosphors, while those containing calcium are greener. Of the two systems, the pyrophosphates are by far the more efficient.

Abstract No. 53

Luminescence of AlN

I. Adams, J. W. Mellichamp, and **G. A. Wolff,** U. S. Army Signal Research and Development Lab., Fort Monmouth, N. J.

An investigation of the electroluminescence (EL), phosphorescence (Ph), and cathodoluminescence (CL) spectra of AlN has been made. The EL spectra show narrow bands in the 400-500 μ region and broad bands in the 500-700 μ region. Phosphorescence shows broad bands in the 300-600 μ region. A suggested excitation mechanism is an energy transfer between the surface and N_2 molecules. The EL was investigated by square-wave input of varying characteristics and parameters.

Abstract No. 54

Crystal Structure and Spectra of Alkali Halide Phosphors

F. D. Klement, Physics and Astronomy Institute, Academy of Sciences of the Estonian S.S.R., Tartu, U.S.S.R.

Luminescence studies were made in crystals undergoing polymorphic transitions induced by temperature and pressure. The effect of hydrostatic pressure on luminescent spectra was also investigated. Vacancies formed in alkali halides activated by divalent impurities were found to associate with the activator ions and give rise to characteristic emission bands. Luminescence in mixed crystals were studied and indications of decomposition of the solid solutions under certain treatment were obtained. These studies also showed that there were preferential sites in the lattice for the activator impurity.

Abstract No. 55

On the Hydrogen-Like Model for Traps in Zinc Sulfide

G. Curie, N. Arpiarian, P. Guéret, and **D. Curie,** Laboratoire de Luminescence, Faculté des Sciences, Paris, France

One of us has proposed for deep traps in ZnS the model of two trapping charges $+e$, associated in neigh-

bor substitutional sites of the lattice. Now the trap depths have been computed for all the possible trapping sites. By a convenient choice of the thermoluminescence rate, almost all the calculated trap depths have been separated effectively. Results are given also for CdS.

Abstract No. 56

A Numerical Table for the Computation of Trap Depths from Thermoluminescence Experiments

G. Curie and **D. Curie,** Laboratoire de Luminescence, Faculté des Sciences, Paris, France

The trap depth E may be computed from the "glow temperature" T° by using the expression, derived from Randall and Wilkins' theory:

$$E^{ev} = \frac{T^{\circ K} - T_0(\beta,s)}{K(\beta,s)}$$

which is accompanied by tables giving the coefficients T_0 and K for different values of the attempt-to-escape frequency s and the rate of heating β. New calculations have been performed; the table now ranges on the interval $10^4 - 10^{15}$ s^{-1} of s-values. Examples of use are given; the table is also extended for the case of a bimolecular mechanism.

Abstract No. 57

Gold-Activated (Zn,CdS Phosphors) Phosphors

M. Avinor, Philips Research Labs., N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands

Gold was shown to produce three emission bands in CdS at 640, 800, and 1150 μ. The long wave band appears when a trivalent metal coactivator is used while the short wave bands are observed with activation by gold alone. The 1.15 μ band in CdS is shown to correspond to the 530 μ gold band in ZnS.

Abstract No. 58

Low-Temperature Luminescence of ZnSCdS Phosphors

R. W. A. Gill and **S. Rothschild,** Mullard Research Labs., Cross Oak Lane, Sulfords, Redhill, Surrey, England

Prener and Weil found little difference between the spectra of ZnSAl or ZnSGa phosphors and ZnSCl or ZnSBr phosphors. The present investigations of ZnSCdS phosphors confirmed this observation for excitation at room temperature. The spectra of self-activated ZnSCdS phosphors were, however, found to differ during excitation at liquid nitrogen temperature.

A band between the self-activated emission and the edge emission, first observed by Kroger with ZnS (NaCl), appeared in several cases depending on the nature of the added impurity and the composition of the atmosphere during firing.

Abstract No. 59

Infrared Stimulation and Quench of Zinc Sulfide Phosphors

C. C. Klick, U. S. Naval Research Lab., Washington, D. C.

Experiments are described on ZnS:Ag, In and ZnS:Ag, Ga phosphors in which the phosphors are continuously excited by ultraviolet light in the region of 3600Å and are exposed to bursts of infrared light over the wave-length range from 7500 to 13,000Å. Room temperature and liquid nitrogen temperature effects are investigated. At low temperatures a large stimulation of the orange emission is found without any quenching. The wave-length dependence of the stimulation is different for the In and Ga samples. It is concluded that the infrared light frees charge carriers from traps which are not the excited states for the orange luminescence.

Abstract No. 60

Synthesis and Crystallography of Structurally Pure Cubic and Hexagonal Single Crystals of ZnS

Harold Samelson and **V. A. Brophy,** Research Lab., Sylvania Electric Products Inc., Bayside, N. Y.

Crystals of ZnS with pure zincblende and wurtzite structures have been reported to occur naturally. ZnS crystals grown synthetically usually show deviations from these pure structures; polytype formation and random faulting have been reported. In the present work, the synthesis and identification of ZnS single crystals of structurally pure zincblende and wurtzite type are discussed. The structure identifications have been made by means of x-ray single-crystal photographs and by optical microscopy using polarized light. The concept of faults in a close-packed diatomic system is discussed, and the effect of faulting on the single-crystal x-ray diffraction patterns is illustrated.

Abstract No. 61

Infrared Absorption of n-Type (Zn,Cd)S

R. M. Potter, Lamp Development Dept., General Electric Co., Cleveland, Ohio.

Free carrier absorption has been found in single crystals of CdS:In and in (Zn,Cd)) S:Ga powders containing up to 60 mole % ZnS. A λ^n dependence of

absorption coefficient was found, where $n = 2.2$ to 3.7. In compositions between 60 and 80 mole % ZnS, evidence was found for absorption due to electrons bound in donor states.

Abstract No. 62

Formation of Phosphor Films by Evaporation

L. R. Koller, Research Lab., General Electric Co., Schenectady, N. Y.

Thin luminescent films of zinc sulfide phosphors have been prepared by evaporation of powder phosphors *in vacuo*. The procedure consists in depositing the film on a heated substrate so that a crystalline rather than an amorphous film is formed. This is accomplished by carrying out the evaporation in a container with walls at the same temperature as the substrate. Cathodo-, photo-, and electroluminescent films have been made by this method. Other phosphors have been made by modifications of this procedure.

Abstract No. 63

Continuous Films of II-VI Phosphors and Photoconductors Made by Vapor Reaction

D. A. Cusano, Research Lab., General Electric Co., Schenectady, N. Y.

During the past several years a large number of continuous films of II-VI and other compounds have been made by improved vapor reaction techniques. Most of these have been zinc-cadmium sulfide phosphors and photoconductors, prepared with groups IB, IIIB, VB, VIIB, and manganese impurities. The salient luminescent, electrical, and electro-optical properties are discussed and, where possible, related to existing data on single crystals or granular material of similar chemical constitution. In addition, methods of fabrication and impurity introduction are described.

Abstract No. 64

Transparent and Powder Phosphor Screens under High Ambient Illumination

A. E. Hardy, Electron Tube Div., Radio Corp. of America, Lancaster, Pa.

The phosphor screen of a cathode-ray tube, operating outdoors in sunlight or in a brilliantly lighted room, is subjected principally to diffuse ambient illumination. Under this condition, better large area contrast can be obtained with certain powder phosphor screens equipped with a low transmission faceplate, than with any transparent phosphor screens now known to exist. The principal reason for this is that, for equal electrical power dissipation, the best powder screens are

10-20 times brighter than the best transparent screens. The use of a low-transmission faceplate (10-20% transmission), with a powder screen, greatly reduces the effect of diffuse ambient illumination. The brightness of truly transparent phosphor screens appears to be limited to 5-10% of their potential brightness due to internal trapping of the luminescent light.

Abstract No. 65

Mechanism of Depreciation of Electroluminescent Phosphors

I. L. Smith, R. M. Potter, and **M. Aven** (present address: Research Lab., General Electric Co., Schenectady, N. Y.), Lamp Development Dept., General Electric Co., Cleveland, Ohio

It is proposed that the short-term depreciation of copper-activated zinc sulfide electroluminescent phosphors is caused by water. The gross features of the depreciation mechanism are similar to the depreciation of zinc sulfide phosphors under ultraviolet excitation. However, while the depreciation of zinc sulfide under ultraviolet excitation affects all exposed parts of the crystallites equally, the depreciation under electroluminescence excitation is confined to localized regions.

Abstract No. 66

Electroluminescence Maintenance

W. A. Thornton, Research Dept., Westinghouse Electric Corp., Bloomfield, N. J.

The maintenance of light emission during the operating life of an electroluminescent phosphors is vital to its practical application as a light source. The maintenance of phosphors of the ZnS:Cu,Cl type has been studied. The dependence on phosphor properties, such as copper and chlorine additions and particle size, on conditions of operation, and on lamp construction is discussed. Changes in properties, other than light emission, and recent maintenance improvements are also described.

Abstract No. 67

Effects of Interaction among Particles in Electroluminescent Layers

A. T. Halpin and **Paul Goldberg,** Sylvania Research Labs., Bayside, N. Y.

The optical and electrical behavior of electroluminescent layers are discussed in terms of experimentally determined properties of individual phosphor grains modified by interactions with neighboring particles. Pronounced interaction effects were found and were studied by determining the dependence of cell brightness and electrical dissipation on variables which alter

the degree of particle-particle interaction, i.e., phosphor volume fraction and fluidity of embedment medium. The role of particle interaction in determining the dielectric properties of the phosphor is discussed in terms of appropriate models.

Abstract No. 68

On the Physical Characteristics and Chemical Composition of Electroluminescent Phosphors

Paul Goldberg and **Sixdeniel Faria**, Chemistry Lab., Sylvania Research Labs., Bayside, N. Y.

Through controlled removal of surface layers, it was found that surface chemical barriers are not responsible for electroluminescence in zinc sulfide phosphors. Polycrystalline phosphors are shown to be almost uniform with respect to chemical, physical, and electroluminescent properties as one passes from the surface into the crystallite bulk. Electron micrographs show the character of the particles as successive layers of phosphor surfaces are removed by acid etching. The experimental results at progressive stages of etching are interpreted in terms of an inefficient surface layer and of changing particle size.

Abstract No. 68A

Detection of Ionization of Eu^{++} in the Phosphor SrS-Eu, Sm by the Paramagnetic Resonance Absorption Method

V. V. Antonov-Romanovsky, V. G. Dubinin, A. M. Prokhorov, Z. A. Trapeznikova, and **M. V. Fock**, P. N. Lebedev Physical Institute, Academy of Sciences of the U.S.S.R., Moscow, U.S.S.R.

When the phosphor SrS-Eu, Sm is under excitation, the paramagnetic absorption caused by Eu^{++} ions decreases appreciably (approximately to 15%). Decrease of the amount of Eu^{++} during excitation may depend either on electron trapping by Eu^{++} ion or on its further ionization, i.e., on its transition to a trivalent state. The second alternative seems to be the most probable.

Abstract No. 69

Copper-Chloride Relationships in Photoluminescent and Electroluminescent Zinc Sulfide Phosphors

A. L. Solomon and **P. Goldberg**, Sylvania Research Labs., Bayside, N. Y.

Photoluminescent ZnS:Cu,Cl prepared with copper concentrations to 3.5×10^{-3} g at./mole are analyzed for copper and chloride. Observed Cu/Cl ratios as a function of copper concentration can be understood in terms of copper and chloride solubility. Photoluminescent properties are functions of both Cu content

and Cu/Cl ratios. By further thermal treatment with copper, low Cu/Cl ratios can be adjusted toward unity. A marked change in photoluminescence is produced and electroluminescence appears. The processes by which these changes are brought about are discussed.

Abstract No. 70

Effect of CdS on the Electroluminescence of ZnS:Cu Halide Phosphors

Arthur Dreeben, RCA Labs., Radio Corp. of America, Princeton, N. J.

Electroluminescent emission intensity, power dissipation, efficiency, and spectral distributions of halide-coactivated (Zn,Cd)S:Cu phosphors have been determined. The extreme sensitivity of brightness to the presence of CdS in these systems and an apparent relationship between brightness and crystal structure are discussed. Cadmium sulfide also causes a variation in the amount of copper retained, particularly in the chloride-coactivated phosphors. Hypotheses to explain these observations are offered.

Abstract No. 71

ZnS:Cu,Cl and (Zn,Cd)S:Cu,Cl Electroluminescent Phosphors

A. Wachtel, Research Dept., Westinghouse Electric Corp., Bloomfield, N. J.

Procedures for the preparation of ZnS:Cu,Cl and (Zn,Cd)S:Cu,Cl electroluminescent phosphors are based on firing in an atmosphere containing elementary S. Cl-incorporation is controlled by firing in capped silica tubes or in open boats in a current of $N_2+S_2Cl_2$. Dependence of brightness on activator concentration is established on the basis of presumably constant excess Cu as Cu_2S. The use of Pb was found to be disadvantageous. Introduction of Cd causes formation of the hexagonal phase and a (Cu,Cd)S compound and simultaneous decrease of electroluminescence brightness as well as dependence of electroluminescence emission color on Cd concentration. A two-step firing procedure is given by means of which this effect may be avoided partially.

Abstract No. 72

(Zn,Hg)S and (Zn,Cd,Hg)S Electroluminescent Phosphors

A. Wachtel, Research Dept., Westinghouse Electric Corp., Bloomfield, N. J.

Solid solutions of (Zn,Hg)S prepared by firing in sealed silica tubes are cubic in structure. With suitable additions of Cu and a coactivator, photoluminescence and electroluminescence are obtained. The electro-

luminescence in the red consists of two emission bands which do not appear to be analogous to the blue and green emission bands of Cu,Cl in ZnS. The quantum efficiency is of the same order of magnitude as that of ZnS:Cu,Cl, but the emission bandwidth is about twice as large and the red electroluminescence consists of emission located to a large extent in the infrared. HgS tends to retain the cubic structure of ternary (Zn,Cd,Hg)S systems, provided that the Cd/Hg ratio does not exceed certain limits; until this is so, the introduction of Cd causes increased electroluminescence.

Abstract No. 73

Influence of Mg and Cd on the Electroluminescence of ZnS:Cu Phosphors

P. M. Jaffe, Research Dept., Westinghouse Electric Corp., Bloomfield, N. J.

The influence of MgS on the electroluminescence of ZnS:Cu phosphors prepared with additions of halogens (F,Cl,Br,I) was investigated. Increasing the MgS content from zero to 8.0 mole % results in a slight progressive decrease in the brightness. Above this concentration the emittance decreases abruptly. The abrupt change can be correlated with a transition from cubic to hexagonal structure in the region of 5.0 to 8.0 mole % MgS. Increasing the MgS concentration also causes an unexpected expansion of the lattice and a shift in emission to shorter wave lengths. In general the results are similar whether Cl, Br, or I is used while F does not appear to enter the lattice. Some investigation of the system (Zn,Cd,Mg)S:Cu,Cl was also made and is discussed.

Abstract No. 74

Influence of Halogen-Coactivator on the Electroluminescence of ZnS:Cu Phosphors, I. Green Emission

P. M. Jaffe, Research Dept., Westinghouse Electric Corp., Bloomfield, N. J.

The use of bromine as coactivator in place of chlorine in electroluminescent ZnS:Cu phosphors results in a change in some of the electroluminescent characteristics. ZnS:Cu,Br and ZnS:Cu,Cl phosphors having similar spectral distributions (green) over a wide frequency range have been prepared. Comparison of brightness as a function of voltage and frequency, brightness waveforms, maintenance, glow curves, efficiency, and temperature dependence of electroluminescence are reported.

Abstract No. 75

Electroluminescent Time Average Light Output of a ZnS:Se Phosphor

J. Mudar, S. Nudelman, and **K. Kamyszek,** Willow Run Labs., University of Michigan, Ann Arbor, Mich.

The time average light output of an electroluminescent phosphor powder has been measured from 10 kcps to 18 mops. Fatigue increases with frequency so that at megacycle operation the output diminishes to 10-25% of initial values with a 30-min period. Mechanically shaking a phosphor-air EL cell after fatigue causes a partial restimulation of light output, with successive fatigue-shake cycles showing a decreasing effect. Electroluminescence and fatigue are temperature dependent.

Abstract No. 76

Temperature-Induced Color Shifts in Electroluminescence

L. W. Strock, Sylvania Lighting Products, 60 Boston St., Salem, Mass.

The color of ZnS:Cu EL-phosphors is determined by the relative intensities of their separate blue and green band emission components for a given condition of excitation. The color of a finished phosphor may be varied over a wide range from blue to green by appropriate thermal treatment in air or other atmosphere. Regardless of Cu-content all phosphors reach their minimum blue/green color ratio at 260°C and, in general, are still green when heated to 400°C, but blue when heated to 150°C.

Abstract No. 77

On the Role of a Stimulating Action of Exciting Light in the Luminescence Kinetics of the Crystalline Phosphor ZnS-Cu

L. A. Vinokurov and **M. V. Fock,** P. N. Lebedev Physical Institute, Academy of Sciences of the U.S.S.R., Moscow, U.S.S.R.

It is shown that electrons' release from traps in ZnS-Cu phosphor by an exciting light leads to decrease of the electron concentration on deep traps with increase of excitation intensity. After removing the excitation, the distribution of electrons over traps gradually approaches equilibrium distribution. A flash under the action of an infrared light is determined mainly by release of electrons from deep levels. Therefore the above effects may be detected by measuring the value of the flash under different intensities of afterglow and at various stages of decay.

Abstract No. 77A

On the Valency States of Manganese in Phosphor Systems

V. V. Osiko, P. N. Lebedev Physical Institute, Academy of Sciences of the U.S.S.R., Moscow, U.S.S.R.

On the basis of oxidized manganese and its total content being measured in about 50 phosphors, the

average valencies of manganese were calculated. Judging from these data there are three groups of phosphors differing from each other in the correlation between the luminescent properties and the valency of manganese. The model system ZnO-MnO-O_2 was studied. The cause of the different valencies of manganese is discussed.

Abstract No. 77B

Physical Processes in Alkali Halide Phosphors Activated by Mercury-Like Ions

Ch. B. Lushchik, I. W. Jaek, G. G. Lüdja, N. E. Lushchik, and **K. K. Schwarz,** Physics and Astronomy Institute, Academy of Sciences of the Estonian S.S.R., Tartu, U.S.S.R.

A number of alkali halide phosphors activated by monovalent and divalent ions having the electronic configuration of neutral mercury were prepared. Diffusion and precipitation of activator ions were investigated as were absorption, emission, and radiationless processes within the impurity center. Energy transfer by means of excitons and electron-hole pairs between the luminescent center, the host crystal and color centers were also studied.

ELECTRONICS—SEMICONDUCTORS

Abstract No. 78

An Apparatus for the Preparation of Semiconductor Grade Silicon

R. C. Ellis, Jr., Research Division, Raytheon Co., Waltham, Mass.

An apparatus is described for the production of large quantities of semiconductor grade silicon. Thermal decomposition of silicon tetraiodide by film boiling is used. The silicon is deposited molten on a submerged induction heated graphite shape and is collected after its departure from the hot zone by flotation. Apparatuses are described for the synthesis and purification of large quantities of silicon tetraiodide.

Abstract No. 79

Twin Generation and Seeding Mechanism in Dendritic Growth

J. W. Faust, Jr., and **H. F. John,** Westinghouse Research Labs., Pittsburgh, Pa.

The formation of twin lamellae at a growing crystal front is discussed in relation to the genesis of dendritic growth arms. The conditions necessary for successful seeding and propagation of a dendrite are discussed in relation to the twin structure and growth button formation. The morphology of the initial growth buttons, as well as subsequent extensions, are described for single crystal, one-twin, and multi-twin seeds.

Abstract No. 80

Propagation of Germanium Dendrites

R. G. Seidensticker and **D. R. Hamilton,** Westinghouse Research Labs., Pittsburgh, Pa.

A formal model is developed for rapid dendritic extension of germanium crystals. The role of corner nucleation is stressed. It is shown that two twin planes are required for the perpetuation of favored corner sites. Two types of sites can occur and cooperate in the extension process. Experimental evidence supports this hypothesis.

Abstract No. 81

Some Aspects of Lateral Growth in Dendrites

H. F. John and **J. W. Faust, Jr.,** Westinghouse Research Labs., Pittsburgh 35, Pa.

Results are presented which show that the lateral growth mechanism is different from that which propagates the dendrite. The growth of the dendrite outward from the central core, which contains the twin structure, to form the final, ribbon-like structure is described. The ways in which various dislocation arrays can arise from the growth process are pointed out.

Abstract No. 82

Dendritic Growth Studies by Pulse Plating Techniques

R. C. Smith, Westinghouse Research Labs., Pittsburgh, Pa.

Pulse electroplating is used to reveal sharp variations of resistivity on germanium dendrites. Good resolution of these variations is obtained in the plate deposited in the meniscus region of the plating solution. Since such resistivity variations must occur during the formation of the dendrite, certain of the growth processes can be deduced from their configuration. At least two processes are indicated, and the evolution of edge structure from small serrations to larger ones is shown to occur.

Abstract No. 83

Growth of Atomically Flat Surfaces on Germanium Dendrites

A. I. Bennett, R. L. Longini, and **W. J. Smith,** Westinghouse Research Labs., Pittsburgh, Pa.

The following theory of formation of extended flat surfaces on germanium dendrites assumes that part of the liquid-solid interface is a supercooled (111) surface. New atomic planes occasionally are nucleated thereon and grow to the melt surface, creating a step on the solid. It is proposed that the meniscus momen-

tarily sticks to this step. Subsequent planes nucleated during this sticking period result in a step several atomic layers high, in accord with experiment.

Abstract No. 84

Dendritic Growth of Indium Antimonide

J. W. Faust, Jr., Westinghouse Research Labs., and **H. Nicholson** and **R. Moss,** Westinghouse Materials Engineering, Pittsburgh 35, Pa.

Dendrites of InSb have been grown and examined by various techniques. The effect of the polar axis is discussed. The internal twin structure and the perfection of the dendrites are described and compared to other dendrites of the zinc-blende structure.

Abstract No. 85

Preparation of Highly Arsenic-Doped Germanium

P. L. Moody and **A. J. Strauss,** Lincoln Lab., Massachusetts Institute of Technology, Lexington, Mass.

In the preparation of germanium single crystals highly doped with arsenic, sealed systems with heated walls must be used to prevent loss of arsenic from the melt by evaporation. Two such systems, a syringe-type Czochralski puller and a three-zone horizontal furnace, are described. The resistivity and Hall mobility at room temperature are reported for concentrations between 10^{18} cm^{-3} and 4.5×10^{19} cm^{-3}, the maximum attained.

Abstract No. 86

Crystal Model Studies of Growth Phenomena in III-V Compounds

R. C. Sangster, Central Research Labs., Texas Instruments Inc., Dallas, Texas

Crystal growth phenomena for III-V semiconducting compounds are discussed. A versatile model has been used to study the behavior of many low indices surfaces in the zinc blende lattice. Results are presented in a series of photographs and discussed in terms of the nature of the bonding, the type, and the packing density of surface atoms. A "stair-step" theory of crystal growth is described.

Abstract No. 87

Orientation Dependent Distribution Coefficients of Tellurium in Indium Antimonide Crystals

J. B. Mullen, Royal Radar Establishment, Malvern, England

The results of distribution coefficient determinations of tellurium in melt grown InSb crystals are discussed.

The anisotropic property of the distribution coefficient has been shown to be connected with the formation during growth of planar crystallographic facets on the solid liquid interface. The "facet effect" is not due to a solute enriched boundary layer. The theoretical significance of the results is discussed.

Abstract No. 88

Anisotropic Segregation in InSb

W. P. Allred and **R. K. Willardson,** Battelle Memorial Institute, Columbus, Ohio

A large variation in segregation coefficients with respect to crystal orientation is observed in InSb. Crystals pulled on the (111) axis show high concentrations of Se and Te in the center of the ingot. This effect is thought to be caused by a segregation coefficient of Se and Te greater than unity on the (111) facet and less than unity on other planes. Radial variations in impurity content as large as a factor of ten have been observed.

Abstract No. 89

Study of Copper Precipitation in Silicon Single Crystals

G. H. Schwuttke, Sylvania Research Labs., Sylvania Electric Products Inc., Bayside, N. Y.

Copper precipitation was studied in silicon crystals of different dislocation density and different impurity concentration. In crystals of high dislocation density ($\sim 10^4$/cm^2 to 10^6/cm^2) copper precipitates only along dislocation lines. In crystals of low dislocation density (less than 10^3/cm^2) random precipitation exists in addition to precipitation along dislocation lines. It was found that the shape of the precipitate varies, depending on the experimental conditions and the nature of the imperfection.

Abstract No. 90

Reactions of Oxygen in Ge

C. S. Fuller, C. D. Thurmond, and **W. Kaiser,** Bell Telephone Labs., Inc., Murray Hill, N. J.

Oxygen in solid solution in Ge undergoes aggregative reactions leading to the formation of donors and ultimately to more complex aggregates. The donor forming reaction is reversible and equilibria are established depending on temperature and oxygen concentration. Solid solutions containing 0.9 to 6.0 x 10^{17} cm^{-3} oxygen have been investigated over the temperature range 325°-527°C. By assuming that four oxygen atoms react successively at a Ge atom to form the singly ionized donor structure, GeO_4, it is possible to fit the experimental curves with a single constant

derived from mass action expressions and the charge and mass balance conditions.

Abstract No. 91

Preparation and Properties of the Pseudo-Binary System GaAs-AlAs

E. P. Stambaugh, J. I. Genco, and **R. C. Himes,** Battelle Memorial Institute, Columbus, Ohio

Means of preparation of homogeneous alloys in the pseudo-binary system GaAs-AlAs have been investigated with emphasis on the gallium-rich region. Degree of homogeneity and composition were determined by x-ray diffraction, electron probe, metallographic examination, microhardness determinations, and chemical analyses. Thermal, electrical, and optical properties as a function of alloy composition and/or temperature are presented.

Abstract No. 92

Preparation and Properties of the Pseudo-Binary System GaSb-AlSb

J. F. Miller, H. L. Goering, and **R. C. Himes,** Battelle Memorial Institute, Columbus, Ohio

Methods of preparation of alloys in the pseudo-binary system GaSb-AlSb were studied, and physical properties were investigated as function of composition and temperature. It has been demonstrated that, with the possible exception of the composition range between 10 and 30 mole % AlSb, solid solution prevails in this system. Melting points, unit cell sizes, energy gaps, resistivity, and hole mobility vary with composition and range between the values of the corresponding properties of the terminal compositions.

Abstract No. 93

Phase Diagram for the Binary System Cadmium-Tellurium

D. R. Mason and **B. M. Kulwicki,** Dept. of Chemical and Metallurgical Engineering, University of Michigan, Ann Arbor, Mich.

The phase diagram for the cadmium-tellurium system has been redetermined by measuring the thermal behavior of representative compositions in the system by the method of differential thermal analysis. Experimental details and the resulting data are described and discussed. Thermodynamic analysis shows that the system CdTe-Te appears to form an ideal solution. The latent heat of fusion of CdTe is estimated to be 10,700 cal/g mole. The system Cd-CdTe is an elementary solution and has a relatively large excess partial molar entropy of solution and a large partial molar enthalpy of solution. These partial molar qualities are independent functions of composition, but not of temperature.

The eutectic compositions have been determined as 10^{-6} atom fraction tellurium and about 0.99 atom fraction tellurium. The validity of this work vis-a-vis that of other investigators is discussed.

Abstract No. 94

Effect of Inhomogeneities on the Hall Coefficient in InSb

R. T. Bate, Battelle Memorial Institute, Columbus, Ohio

Crystals of n-type InSb have been grown which were doped with selenium and pulled in such a way that the selenium segregated during growth to produce large impurity gradients. These impurity gradients were mapped and their effect on the galvanomagnetic coefficients determined. Results indicated very pronounced effects, such as an increase of the Hall coefficients at room temperature by nearly a factor of two, as the magnetic field is increased from 1000 to 20,000 gauss.

Abstract No. 95

Properties of P-Type GaAs Prepared by Copper Diffusion

F. D. Rosi, D. Meyerhofer, and **R. V. Jensen,** RCA Labs., Radio Corp. of America, Princeton, N. J.

Purification of arsenic by hydrogen sublimation and gallium by vacuum annealing resulted in the preparation of high resistivity ($\sim 10^6$ ohm-cm), n-type GaAs crystals by the horizontal Bridgman technique. Conversion of this material to p-type was accomplished by the inward diffusion of copper from the crystal surface. Measurements of Hall mobility as a function of hole concentration in the range 2×10^{16} cm^{-3} to 3×10^{17} cm^{-3} at room temperature showed a dependence which is consistent with theory. The analysis suggests a lattice mobility for holes of 450 cm^2 v^{-1} at 300°K. The mobility varied approximately as $T^{-2.8}$ in the range 76°-300°K. At the low temperatures the number of ionized impurities ranged from 2×10^{15} cm^{-3} to 1×10^{16} cm^{-3}. Energy levels associated with copper in GaAs are 0.023 ev and 0.15 ev above the valence band.

Abstract No. 96

Preparation and Properties ZnSb

R. C. Bourke, R. Simon, and **E. H. Lougher,** Battelle Memorial Institute, Columbus, Ohio

Homogeneous specimens of ZnSb have been prepared by a modified hot-pressing method, using a graphite die. Specimens thus prepared are consistently single-phase material and, in this respect, are superior to specimens prepared by a quench-and-anneal method. The temperature dependences of resistivity, Hall

coefficient, Hall mobility, and thermoelectric power of several specimens have been determined. In contrast to other reports, stoichiometric, hot-pressed ZnSb has been found to have a room temperature resistivity of 0.6 ohm-cm, a corresponding thermoelectric power of 700 v/°K and Hall mobility of 220 cm^2/v-sec. A value of 0.3 ev for the energy gap at 0°K has been calculated from electrical data. A study was made of the effect of Sn and Pb additions to stoichiometric ZnSb. Lead-doping, even to the point of saturation, failed to affect the Hall coefficient of the compound substantially. Tin, however, was found to be an effective *p*-type doping agent.

Abstract No. 97

Preparation and Properties of Gallium Phosphide

C. J. Frosch, M. Gershenzon, and **D. F. Gibbs** (present address: H. H. Wills Physics Lab., Bristol, England), Bell Telephone Labs., Inc. Murray Hill, N. J.

A pressure chamber is described for producing solid multicrystalline ingots of gallium phosphide at high phosphorus pressures. Bars cut from these ingots are being employed in an investigation of the floating zone technique for growing controlled single crystals of gallium phosphide. Methods for overcoming new problems encountered in the floating zone processing are described. The current status of the floating zone investigation is described. Electrical measurements are reported on single crystals cut from multicrystalline ingots and bars purified by floating zone recrystallization.

Abstract No. 98

Preparation and Characteristics of P-N Junctions in Gallium Phosphide

M. Gershenzon and **R. M. Mikulyak,** Bell Telephone Labs., Inc. Murray Hill, N. J.

Techniques for the preparation of both diffused and alloyed GaP diodes are described as well as the thermal and chemical stability of these structures. The presence of recombination-generation centers and a highly compensated region leads to departures from ideal junction behavior in the forward and reverse currents, reverse capacity, and in long time constants found for establishing steady-state conditions. Room temperature breakdown potentials to 135 v and rectification ratios to 3×10^6 are reported.

Abstract No. 99

Preparation and Properties of Grown P-N Junctions of InSb

H. C. Gorton and **F. J. Reid,** Battelle Memorial Institute, Columbus, Ohio

Grown p-n junctions of InSb have been prepared by adding zinc to a high-purity melt. After the junctions had been grown, the material on the n-type side had electron mobilities greater than 350,000 cm^2/v-sec at 77°K and carrier concentrations in the $10^{14}/cm^3$ range. Junction characteristics were obtained as a function of temperature in the range of 55°-200°K. The data show the effects of surface conditions and of intrinsic carriers on the reverse current.

Abstract No. 100

Influence of Crystal Size on the Spectral Response of Evaporated PbTe and PbSe Photoconductive Cells

W. D. Lawson and **A. S. Young,** Royal Radar Establishment, Malvern, England, and **F. A. Smith,** Atomic Energy Research Establishment, Harwell, England

Photoconductive layers of PbTe have been formed by evaporation on substrates at different temperatures. The size of crystals in the layers has been estimated from electron micrographs and x-ray diffraction, and a correspondence has been obtained between crystal size and the limit of spectral response. Sensitivity up to the long wave-length limit set by the energy gap cannot be achieved unless the crystals are greater than a critical size; for lead telluride this is about a quarter of a micron. A similar effect has been shown to occur with PbSe.

Abstract No. 101

On the Mechanism of Chemically Etching Germanium and Silicon

D. R. Turner, Bell Telephone Labs., Inc., Murray Hill, N. J.

The electrode potential of germanium or silicon in a chemical etching solution is a function of: solution pH, rate of etching, physical condition of the surface, conductivity type, and resistivity. The results suggest that excess holes and electrons are produced at the surface of the semiconductor during chemical etching. Holes are injected at cathode sites, but only a portion of these holes are consumed at anode sites since the anode reaction involves current multiplication.

Abstract No. 102

Experimental Micro-etch Techniques on Millimeter Wave-length Diodes

D. G. Langlais, Philco Corp., Philadelphia, Pa.

Use of transistor micro-etch techniques has improved the sensitivity of 4.3 mm mixer diodes by approximately 3 db. Reduction of the germanium blank base thickness by jet-etching to about 0.06 mil and back-alloying have produced an "effective" base thickness of 0.02-0.03 mil (an order of magnitude less than

whisker contact radius). The average spreading resistance was lowered from 14 ohm (Philco 1N2792 mixer diode) to 8 ohm as expected by micro-etch theory. Selection of jet-etching conditions yielded a flat window area diameter of approximately 6 mil, thereby reducing close alignment tolerances.

Abstract No. 103

Oxide Masking of Solid SiO_2 against Boron

Frank Keywell and **Marshall Nechtow,** Hughes Semiconductor Products, Newport Beach, Calif.

Silicon dioxide films 2000Å thick on high resistivity n-type silicon were exposed at 1100°C to a boron source for a few minutes. A liquid borosilicate phase penetrated more than 700Å but did not reach the parent silicon. The samples were next placed in a furnace at 950°C for 10 weeks. Boron atoms did not penetrate the solid quartz during the 10-week heat treatment, hence the diffusion coefficient of boron in solid quartz is less than 3.1×10^{-19} cm²/sec. The low diffusion coefficient is due to chemical bonding between boron and oxygen atoms.

Abstract No. 104

Oxidation-Induced Diffusion in Silicon

H. W. Cooper, E. I. Doucette, and **R. A. Mehnert,** Bell Telephone Labs., Inc., Murray Hill, N. J

The formation of thermal oxide layers on silicon causes a redistribution of bulk impurities which may either be gettered at the oxide-bulk interface or be rejected into the crystal. For silicon, whose oxide grows at a parabolic rate, a rigorous solution has been obtained. The impurity concentration follows a complementary error function distribution with a constant surface concentration.

Silicon with aluminum and antimony as major and minor impurities was used to verify the theory quantitatively. The observed junction depths corresponded well in magnitude and rate of increase with that predicted. A radio-tracer technique was used to determine the segregation of indium at the silicon-silicon oxide interface. A value near unity was observed.

Abstract No. 105

Gaseous Diffusion of Arsenic in Germanium

Carl Pihl and **Kurt Lehovec,** Sprague Electric Co., North Adams, Mass.

Previous studies of the gaseous diffusion of phosphorus in germanium have been extended to include vapor diffusion of arsenic in germanium. Data are presented on surface concentration of arsenic in ger-

manium as a function of arsenic pressure in the gas phase. At sufficiently high arsenic concentrations a liquid phase of germanium arsenide forms and this phase has been identified by electron diffraction. Evidence is presented that this liquid phase suppresses thermal conversion.

Abstract No. 106

Open Tube Diffusion of Antimony into Germanium

A. E. Blakeslee, Bell Telephone Labs., Inc., Allentown, Pa.

A two-step, three-furnace process for the diffusion of antimony into germanium is described. Sheet resistivity and junction depth data are presented as functions of time of diffusion and temperatures of the three furnaces, and empirical expressions are given for sheet resistivity in terms of the three temperatures. The impurity distributions resulting after each of the two diffusion steps are discussed. Diffusion constants found for the temperature range 600°-700°C are lower than values published for sealed tube systems.

Abstract No. 107

Surface Concentration of Indium in Germanium from Gaseous Diffusion, II

Karl Busen and **Earl Meeks,** Sprague Electric Co., North Adams, Mass.

Previous investigations on the indiffusion of indium from the vapor phase into germanium at 837°C are now extended to diffusion temperatures of 775° and 900°C. The experiments are carried out again in a specially designed closer system, and values for the surface concentration of indium in the germanium for different indium vapor pressures are presented. Diffusion coefficients of indium in germanium derived from our experiments are compared with published values.

Abstract No. 108

A Diffusion Mask for Germanium

E. L. Jordan and **D. J. Donahue,** Semiconductor and Materials Div., Radio Corp. of America, Somerville, N. J.

A technique has been developed for the deposition of a silicon dioxide diffusion mask on the surface of germanium. The silicon dioxide coatings are formed by the thermal decomposition of an organic-oxy-silane. Patterns are formed in the silicon dioxide coating by the photoresist-acid etch techniques that are well known in silicon technology. The mask is completely effective against donor impurities in all concentrations

and against acceptor impurities in low and medium concentrations. The use of the mask has permitted the construction of a double diffused n-p-n mesa germanium transistor.

Abstract No. 109

Diffusion of Phosphorus in Silicon

I. M. Mackintosh, Bell Telephone Labs., Inc., Murray Hill, N. J.

A process is described for producing N-type, phosphorus-diffused layers in silicon. The diffusions are carried out in a closed system, using as the diffusion source a glass consisting of P_2O_5 and CaO. Surface concentrations between 10^{21} and 10^{16} cm^{-3} can be obtained with reproducibilities between 2% and 20%, junction depths from about 0.02 mil upward with reproducibilities between 2% and 5%. The process is compatible with the oxide masking of layers with surface concentrations as high as 10^{21} cm^{-3}. Data are presented for the diffusion coefficient, and the value of the activation energy for this process is discussed.

Abstract No. 110

Experimental Evidence of Surface Damage and Precipitation in Diffused Silicon

L. Gerlach and **R. Haberecht,** P. R. Mallory and Co., Indianapolis, Ind.

Visible evidence of surface damage and precipitation in diffused silicon is presented. Variations in the junction formation related to abnormal concentration gradients and the presence of a precipitated phase is discussed in relation to the basic mechanism of precipitation. Evidence indicates that the oxygen distribution and a critical concentration of diffusant are the important factors necessary for the presence of a precipitate.

Abstract No. 111

Precision Lapping, Damage, and Diffusion

C. J. Spector and **T. E. McGahan,** Bell Telephone Labs., Murray Hill, N. J.

Silicon slices have been lapped experimentally and polished to less than 0.003 in. with opposing faces optically plane and parallel to within 0.00002 in. Modified planetary lapping techniques have been used so that the strains usually induced by "one side at a time" processes are absent. Data are presented to correlate rate of lapping, depth of damage (measured by x-ray "rocking angle" techniques), and impurity diffusion parameters with abrasive particle size.

Abstract No. 112

A New Solution to New Diffusion Equation and a New Application of Analog Solutions

R. Moore and **J. Colburn**, General Electric Co., Syracuse, N. Y.

An analytical expression for the diffusion profile obtained during the two-step diffusion process for the germanium mesa transistor has been developed by two independent analyses. The form of this equation makes numerical solutions difficult; however, some curves obtained by digital means are presented. A more direct approach is the use of a passive electrical analog. The analogy is shown together with some of the curves obtained, and these are shown to be equivalent to the analytical results.

Abstract No. 113

Localized Breakdown in Diffused Silicon Junctions

B. D. James and **P. S. Flint**, Fairchild Semiconductor Corp., Palo Alto, Calif.

In diffused silicon junctions, localized regions of low breakdown have been found associated with "pipes" of the same doping as the bulk material that connects the bulk with the surface through the diffused layer. These pipes are much more highly doped than the bulk silicon. The frequency of their occurrence is enhanced by oxidation of the silicon prior to diffusion, and they are interpreted as arising from segregation of the bulk dopant around vacancy clusters.

Abstract No. 114

(There is no Abstract 114)

Abstract No. 115

Production of a Germanium PNPN Switching Transistor by Post-Alloy Diffusion

Fred Barson and **John Gow**, International Business Machines Corp., Poughkeepsie, N. Y.

A process has been developed for fabricating a three-terminal Germanium PNPN Switching Transistor similar to that described Klein and Kordalewski. By employing post-alloy diffusion techniques it is possible to produce the four-layer structure completely during the alloying process, with no prediffusion required. Furthermore, the device parameters can be varied within certain limits simply by changing the impurity concentration of the alloy pellets. Details of the pro-

cess are described, and typical device characteristics listed.

Abstract No. 116

A High-Frequency PNP Diffused Silicon Transistor Produced by the Oxide Masking Technique

O. Stavik, Northern Electric Co., Montreal, Que., Canada

A high-frequency PNP diffused silicon transistor has been developed which has electrical characteristics very similar to the NPN diffused silicon "Mesa" transistor. Silicon slices of resistivity 0.5-0.7 ohm-cm are first diffused with arsenic to a depth of 5 μ. During this first diffusion an oxide layer is formed on the slice which is sufficiently thick to mask against the second diffusant, namely, boron. Oxide is removed from the silicon surface in the form of stripes and boron diffused through these areas to a depth of 4 μ to produce emitter junctions, thus giving a base layer of 1.0 μ. The alpha cut-off frequency ranges from 50 to 100 mcs. Grounded emitter current gain as high as 200 has been measured. V_{ceb} is of the order of 50-60 v.

Abstract No. 117

(There is no Abstract 117)

Abstract No. 118

Physical Metallurgy in Semiconductor Device Fabrication, I. Gold Electrode Attachments to Silicon and Germanium

L. Bernstein, B. G. Bender, and **W. B. Warren,** Hughes Products, P. O. Box 278, Newport Beach, Calif.

Results of separate studies of large and small area attachments are discussed. Metallurgy and choice of backing material to avoid cracking is described. Compositions of gold-tin offer the most versatile attachment in a variety of atmospheres. Eleven photomicrographs and two plates of expansion curves are presented.

Abstract No. 119

Physical Metallurgy in Semiconductor Device Fabrication, II. Studies of Gold-Aluminum and Gold-Tin Electrode Attachment

L. Bernstein, W. B. Warren, and **B. G. Bender,** Hughes Products, P. O. Box 278, Newport Beach, Calif.

Electrode attachments to aluminum-silicon eutectic regions in semiconductor devices by means of gold or gold alloys often produce a condition referred to as the "purple plague," the $AuAl_2$ phase formation, with subsequent mechanical failure. Conditions which promote

its formation in addition to the more desirable Au_2Al phase are discussed. Wetting and surface tension problems associated with attachments to the Al-Si surface via gold-tin alloys are described in connection with gold-aluminum compound formation. Thermal expansion data for the systems involved are presented, along with eighteen color photomicrographs of the various conditions.

Abstract No. 120

Effects of High Aluminum Concentration in Emitters of Germanium Alloyed Power Transistors

H. K. Becherer and **Ernest Paskell,** Delco Radio Div., General Motors Co., Kokomo, Ind.

This paper presents a survey of the effects of an emitter alloying with more than 2% aluminum on high power transistors. Slides show that besides the wettability between indium and germanium the regrown structure as well as the shape of the p-n junction edges will be changed. A single alloying process with Al-In alloy will give immediately the new junction shape while a re-alloying onto a pre-alloyed emitter junction will correct the previous junction. Electrical data are given to shown the gain at higher current.

ELECTROTHERMICS AND METALLURGY

Abstract No. 121

Resources of Vanadium Minerals—Domestic and Foreign

Staff Member, Colorado School of Mines Research Foundation, Inc., Golden, Colo.

This paper covers the geology and occurrence of vanadium deposits in the United States and various foreign countries including Finland, Transvaal, Quebec, Peru, and miscellaneous sources. Deposits of vanadium with uranium in sandstone and limestone ores are discussed as being one of the principal sources. Potential vanadium recovery from magnetite deposits, vanadiferous phosphates and shales, vanadate ores, and minor sources are discussed.

Abstract No. 122

Mining and Beneficiation of Vanadium Minerals

Staff Member, Colorado School of Mines Research Foundation, Inc., Golden, Colo.

Mining and beneficiation of the carnotites and roscoelite ores for vanadium recovery as practiced at present are discussed. Beneficiation processes for recovery of vanadium from other sources, including titaniferous magnetites, vanadiferous shales, ferrophosphorus

from western phosphates, and as a by-product from wet process phosphoric acid production are also described.

Abstract No. 123

Mineralogy and Geochemistry of Vanadium in the Colorado Plateau

A. D. Weeks, U. S. Geological Survey, Washington, D. C.

The chief domestic source of vanadium in uraniferous sandstone in the Colorado Plateau. Vanadium is 3-, 4-, or 5-valent in nature and, as oxides or combined with other elements, it forms more than 40 minerals in the Plateau ores. These ores are discussed with regard to relative amounts of vanadium silicates and oxide-vanadates, uranium-vanadium ratios, progressive oxidation of black low-valent ores to high-valent carnotite-type ores, and theories of origin.

Abstract No. 124

Vanadium by Metallic Reduction of Vanadium Trichloride

M. J. Ferrante and **F. E. Block,** U.S. Dept. of the Interior, Bureau of Mines, P.O. Box 492, Albany, Ore.

Vanadium tetrachloride was made by chlorinating vanadium oxide with chlorine in the presence of carbon. By refluxing vanadium tetrachloride it decomposed to vanadium trichloride which is nonvolatile. The allowed volatile oxychloride to be separated. The trichloride was reduced with magnesium or magnesium-sodium mixtures under inert atmosphere. Excess reductant and by-product salts were removed from the vanadium sponge by vacuum distillation. Arc-melted vanadium was 99.8+% pure and could be cold-rolled into thin sheets.

Abstract No. 125

Electrorefining of Vanadium

D. H. Baker, Jr., and **F. R. Cattoir,** Bureau of Mines, Boulder City Metallurgy Research Lab., Boulder City, Nev.

The fused salt electrorefining technique has been applied successfully to vanadium. The electrolyte was sodium chloride containing 3-6% vanadium as vanadium dichloride. Current efficiency was approximately 91%. Oxygen and nitrogen impurities were reduced by two thirds of the amount contained in the feed material. The hardness of the product was reduced from 97 Rockwell B to 35 R_B. Arc melted ingots could be given a 99% cold reduction by rolling before edge cracking appeared.

Abstract No. 126

Preparation of High-Purity Vanadium Metal by the Iodide Refining Process

O. N. Carlson and **C. V. Owen,** Iowa State University, Ames, Iowa

The preparation of vanadium of 99.9+% purity by the Van Arkel-deBoer iodide process is described. Conditions for optimum growth rate and maximum purity were determined. Data on impurity transfer from the feed to the hot filament are presented together with a discussion of contamination by the retort. The quality of vanadium obtained from feed material prepared by bomb reduction and by a sponge process was compared. An apparatus designed to prepare several pounds per batch is described. A few physical properties were determined and are also reported.

Abstract No. 127

Consolidation and Fabrication of Vanadium

T. W. Merrill, Research Center, Vanadium Corp. of America, Cambridge, Ohio

Calcium reduction of the oxide is the commercial method used for preparation of vanadium in this country. The regulus obtained is normally arc melted in vacuum; electron beam melting also has been tried. The oxygen content is lowered by either melting process. Hot working is practicable, providing reasonable precautions are taken to avoid excessive oxygen contamination. The metal can be cold rolled, swaged, and drawn, provided the contaminated layer resulting from hot working is completely removed. Warm extrusion of small ingots was found to be a good processing method. Tubing, plates, strip, foil, rods, and wire have been produced in trial quantities.

Abstract No. 128

Mechanical Properties of Unalloyed Vanadium

J. W. Farrell, Technology Dept., Product Development Lab., Union Carbide Metals Co., Division of Union Carbide Corp., Niagara Falls, N. Y.

Mechanical properties are summarized for unalloyed vanadium consolidated by consumable-electrode arc melting. The following data are presented for both cold-worked and annealed samples with varying interstitial contents: short-time tensile properties from —196° to +1100°C, yield point and strain-aging phenomena, room temperature notched tensile properties and true stress-true strain data, the room temperature flow constants and elastic modulus, work-hardening characteristics, bend test data, Erichsen test data, crystal orientations, and metallographic techniques.

Abstract No. 129

Lattice Parameter and Expansion Coefficient of Vanadium

W. J. James and **M. E. Straumanis,** School of Mines and Metallurgy, University of Missouri, Rolla, Mo.

The lattice parameter of 99.972% pure vanadium prepared at Battelle by the Van Arkel method were determined by the asymmetric diffraction technique over the temperature range 10°-60°C using unfiltered copper radiation. From the $\alpha(321)$ line with $\theta = 72.5°$ a value of a = 3.0241Å at 25°C, corrected for refraction, was obtained. The computed closest atom-to-atom distance was 2.1384Å. The linear expansion coefficient was 9.96×10^{-6} $(°C)^{-1}$. Calculated x-ray density at 25°C was 6.121 ± 0.002 g cm^{-3}. A plot of lattice parameters vs. summation of nitrogen and oxygen content when extrapolated to 0% showed a decided decrease in lattice parameter.

Abstract No. 129A

Corrosion Properties of High-Purity Vanadium

David Schlain and **C. B. Kenahan,** U. S. Dept. of the Interior, Bureau of Mines, Region V, College Park, Md.

The chemical and galvanic corrosion behavior of high-purity vanadium was investigated by the Bureau of Mines, U. S. Department of the Interior, at its College Park, Md., Metallurgical Research Center. Vanadium was found quite resistant in hydrochloric, sulfuric, and phosphoric acids, but corroded rapidly in nitric acid solutions. It resisted corrosion in substitute ocean water, 3% sodium chloride solution, 10% sodium hydroxide solution, and tap water, but not in 5% mercuric chloride or 20% ferric chloride solutions. Vanadium was resistant in acetic, lactic, citric, and tartaric acids and corroded slowly in oxalic and formic acids.

Abstract No. 130

On the Constitution of Some Vanadium-Base Binary and Ternary Systems and the Aging Characteristics of Selected Ternary Alloys

S. Komjathy, Armour Research Foundation, Technolgy Center, 10 W. 35 St., Chicago 16, Ill.

To promote development of vanadium-base alloys, binary (V-Hf, V-Re, V-Sn, V-Th, V-W) and ternary systems (V-Ti-Nb, V-Ti-Mo, V-Ti-Ta, V-Ti-W, V-Ti-O, V-Ti-Si, and V-Ti-Be) were investigated to determine: (*a*) extent of the vanadium-rich solid solution between 800° and 1500°C; (*b*) character of the second phase in equilibrium with the solid solution; and (*c*) melt reactions. The age-hardening of selected V-Ti-O, V-Ti-Si, and V-Ti-Be alloys was studied at 550°, 650°, and 750°C.

Abstract No. 131

Development of Improved Vanadium-Base Alloys for High-Temperature Purposes

B. R. Rajala and **R. J. Van Thyne**, Armour Research Foundation, Technology Center, 10 W. 35 St., Chicago 16, Ill.

Vanadium-base sheet alloys containing titanium and/or columbium, molybdenum, tantalum, and tungsten exhibit excellent strength at elevated temperatures and weldability. Since oxidation protection was not an aim of this program, tensile, creep, and short-time rupture properties were determined in enert atmospheres. These alloys with outstanding cold fabricability are nearly equal to the best 2000°F sheet materials on a density corrected, 15-min rupture basis.

Abstract No. 132

Properties of Vanadium-Base Alloys

S. T. Wlodek, Metals Research Labs., Union Carbide Metals Co., P. O. Box 580, Niagara Falls, N. Y.

Development of a novel series of vanadium-base alloys combined with the IVB and VB group elements is described. High-strength, low-density compositions possessing good aqueous corrosion resistance in boiling oxidizing, or reducing, acids and sufficient oxidation resistance to allow their fabrication by conventional hot-working techniques in air can be designed. Properties estimated under inert atmosphere conditions include ultimate tensile strength of 120,000 to 35,000 psi over the temperature range 700°-1000°C and stress-rupture properties at 700°C corresponding to 100-hr life at stresses in excess of 100,000 psi. The alloy design principles responsible for these improvements of vanadium are discussed.

Abstract No. 133

Canada's Interest in Methods of Reducing Iron Ores

John Convey, Mines Branch, Dept. of Mines and Technical Surveys, Ottawa, Canada

Canada is well supplied with those resources which may be used in the production of iron, i.e., ore, coal, oil, natural gas and electric power. For that reason our metallurgical industries and research organizations have become much interested in the various methods of reducing iron ores. Our government Department of Mines and Technical Surveys in Ottawa has experimental facilities which may be used to assist in determining the reduction methods which would be most suitable in different parts of the country.

Abstract No. 134

Economic and Process Factors Affecting the Selection of a Direct Reduction Process

D. C. Brown, Jones and Laughlin Steel Corp., Pittsburgh, Pa.

A direct reduction process will prove best for all applications under all circumstances. Many process and economic factors will go together to dictate which process best fits a specific application. This paper describes the influence of physical and chemical characterization of the ore on (*a*) reduction kinetics, (*b*) type of equipment used, and (*c*) pre- or post-beneficiation or both. The effects of type in availability of fuel for both reduction requirements and process heat with the attendant effects on post-beneficiation and compaction are discussed. Other factors such as plant location, freight, use of direct reduction product, and degree of metallization are considered.

Abstract No. 135

Solid Fuels and Reductants for the Beneficiation and Reduction of Iron Ores

H. U. Ross, Dept. of Metallurgy, University of Toronto, Toronto, Ont., Canada

The advantages in using solid fuels in the beneficiation and reduction of ores are outlined. Those properties of certain types of solid fuels, which make them particularly suitable, are discussed. The great importance of the availability of coking coal on the choice of reduction process is stressed. Research and development work on direct reduction processes has been greatly stimulated by the rapid exhaustion of the reserves of low-volatile coking coals.

Abstract No. 136

Gas Reactions in Reduction Processes

J. Huebler, Surface Combustion Div., Midland Ross Corp., Toledo, Ohio

Reactions of the gases used in the reduction of the iron oxides are discussed from the standpoint of the generation of these gases either within the process or in external apparatus and from the standpoint of the reactions which occur in the reduction. An effort is made to present in a simple fashion the reasons for the reactions, reaction rates, and heat requirements for the process.

Abstract No. 137

Magnetizing Roasting

D. J. Hains, Engineering Co., Ltd., Toronto, Ont., Canada

The beneficiation of iron ores by magnetizing roasting in the rotary kiln is dealt with. The process is particularly useful in treating mixed ores due to the possibility of controlling and varying the gas atmosphere and temperature throughout the length of the kiln. Pilot and commercial plant equipment are illustrated and metallurgical results on various typical ores are reported.

Abstract No. 138

How Are the Blast Furnaces Doing?

O. R. Rice, Koppers Co., Inc., Pittsburgh, Pa.

The currently demonstrated advances in unit productivity, coke economy, etc., are dealt with, and the changed circumstances that have brought about these advances in the blast furnace art are cited. Speculation is made as to what the near future may hold with respect to blast furnace performance, as intimated by already-initiated procedures. The role played by blast furnace hot metal in the manufacture of steel is emphasized.

Abstract No. 139

Performance of the First Commercial H-Iron Reduction Plant

H. H. Stotler, Hydrocarbon Research Inc., New York, N. Y. and **R. A. Lubker,** Alan Wood Steel Co., Conshohocken, Pa.

Performance of a 50 ton per day plant in which hydrogen from coke oven gas reduces iron oxides in a fluidized bed below 1000°F and 500 psig is discussed. Operation of the plant has demonstrated the flexibility of a single unit and the versatility of the product. Operation of a three-stage unit is also discussed; performance in the commercial unit is compared with laboratory results; an economic evaluation is given of a projected 1000 ton per day plant.

Abstract No. 140

The Nu-Iron Process—A Fluidized Bed Process for Reducing Iron Ore

T. F. Reed, J. C. Agarwal, and **E. H. Shipley,** United States Steel Corp., Monroeville, Pa.

In the Nu-Iron fluidized bed reduction process preheated minus 10-mesh high-grade ore is reduced continuously with preheated hydrogen at 1300°F and 50 psig pressure in two separate steps, $Fe_2O_3 \rightarrow FeO \rightarrow Fe$. The flow of iron ore and the hydrogen are countercurrent. The unused hydrogen in the off gases from the reduction reactor is recovered and recycled. A description of the Nu-Iron pilot plant and the commercial embodiment of the process is included.

Abstract No. 141

Direct Reduction of Fine Iron Ore Concentrates in a Self-Agglomerating Fluidized Bed

F. M. Stephens, Jr., and **B. G. Langston,** Battelle Memorial Institute, Columbus, Ohio

This paper describes a process which utilizes the adhesive properties of the reduced iron particles for self-agglomeration of finely ground iron concentrates in a fluidized-bed reactor. Data are presented which show that the self-agglomeration mechanism can be controlled by the distribution of the surface areas of the particle-size fractions in the bed, the temperature, and the space velocity used in the fluidized-bed reactor.

Abstract No. 142

The Esso Research-Little Process

R. W. Hyde, Arthur D. Little Inc., Cambridge, Mass.

The Esso Research-Little process is a method for continuously reducing finely divided iron ore in a 3-stage fluidized-bed system using hydrocarbons, gaseous or liquid, as the source of both reducing agent and the heat required for the reduction. The paper includes a description of the experimental work, both laboratory and pilot plant, from which the Esso Research-Little Process was evolved.

Abstract No. 143

Present Direct Reduction Research at Stora Kopparberg, Sweden

T. O. Dormsjo, Stora Kopparberg Corp., New York, N. Y.

This paper discusses the Wiberg-Soderfors process: development, current results, possible modifications: the Stelling process using carbon monoxide. Rotary kiln reduction: the Kalling method. Magnetizing reduction for beneficiation purposes.

Abstract No. 144

The R-N Process

J. S. Breitenstein, R-N Corp., 111 Broadway, New York, N. Y.

A recent test on a 50 ton iron per day scale has demonstrated substantially greater kiln thruputs than previously projected. Large scale commercial electric and open hearth melting tests on R-N briquettes have been performed recently. This paper discusses the results of these melting tests as well as the latest information developed in the semi-commercial plant in Birmingham; in addition, a presentation is made on the new facilities installed in Birmingham, such as charring and balling, and the integration of these units in the R-N flowsheet.

Abstract No. 145

Reasons for the Co-Current Kiln in Direct Reduction

Horace Freeman, Freeman Corp., Cap-de-la-Madeleine, Quebec

The author has operated both counter-current and co-current rotary kilns for the direct reduction of iron ores. He gives his reasoning for finally adopting the co-current kiln for commercial use. In this kiln the ore, reducing carbon, and sulfur-absorbing limestone are fed together at the firing end and travel with the combustion gases to the discharge end. The results obtained with various types of natural and pretreated ores and types of reducing carbon are reported.

Abstract No. 146

Allis-Chalmers Agglomeration-Reduction Process

T. G. Kirkland, C. L. Sollenberger, and **J. Platner,** Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

(No abstract received)

Abstract No. 147

Direct Reduction Research at IRSID

J. Astier, Institut de Recherches de la Siderurgie, Maizieres-les-Metz, France

Two programs are discussed: (1) aiming to reduce low-grade French ores with coal in rotary kilns; low-temperature tests at the U.S. Bureau of Mines (Laramie, Wyo.) with beneficiation of reduced ore; Krupp Renn tests at Kraluv Dvur (Czechoslovakia); high-temperature tests at Azincourt (France) to make molten pig iron, and [2] to reduce high-grade ores or concentrates with natural gas; low-temperature gas reduction, and electric steelmaking compared with direct production of pig iron or steel.

Abstract No. 148

The Jet Smelting Process

R. L. Cavanagh, Ontario Research Foundation, Toronto, Ont., Canada

The process is outlined, and some reasons are given for the interest in this type of direct reduction process. The original research program is summarized and preliminary tests commented on. Some results of a feasibility study, including theoretical calculations, are presented. Detailed results of furnace experiments and a resume of the present status of the work are given. Approximate estimates of possible costs are made.

Abstract No. 149

Electric Smelting and Melting

H. Walde, Demag-Elektrometallurgie, GmbH, Duisburg, Germany

(No abstract received)

Abstract No. 150

Consideration of Fuel Requirements for Iron Ore Reduction

R. Wild, The British Iron and Steel Research Association, London, England

The possible methods of making iron are reviewed and classified according to the quantity of reducing agent used and the energy requirements. The generation of the required energy is considered, and the effect of the efficiency of reduction is shown graphically. The known ironmaking processes are compared on the basis of their energy requirements. The influence of the available fuel, and other factors, on the choice of process is discussed.

Abstract No. 151

Strategic-Udy Process for Smelting Iron Ores

M. C. Udy, Strategic-Udy Processes Inc., Niagara Falls, N. Y.

The Strategic-Udy Process has opened a new vista of metallurgy by cutting the blast furnace into two parts. The "top part," now placed on its side and rotated, gives control of preheating and prereduction not attained in the blast furnace. Electrodes, placed in the "bottom part," provide heat and the air has been turned off. Now that carbon, silicon, phosphorus, etc., can be controlled in the product, low or off-grade ores and reductants may be used.

Abstract No. 152

Technical and Economic Factors to Be Considered in the Electric Furnace Reduction of Iron Ores

N. H. Keyser, Process Metallurgy Div., Battelle Memorial Institute, Columbus, Ohio

This paper traces changes in technology and economics that have prompted the present-day intense interest in the use of electric furnaces for reducing iron ores. The reasons for interest in "pretreatment" and "prereduction" ahead of the electric smelting furnace are explained. Emphasis is placed on the fundamentals behind the various processes that utilized electric furnaces rather than describing specific processes. Emphasis is placed on factors that influence costs rather than specific costs.

Abstract No. 153

Electric Smelting of Iron Ores

F. C. Collin, Elektrokemisk A/S, Oslo, Norway

The paper deals with growth and geographical distribution of electric pig iron smelting plants with special reference to the developments in Norway and Japan. Recent progress in preparation of sinter and the sizing of coke is emphasized. Thereby increased indirect reduction has been established, and carbon as well as power consumption reduced correspondingly. Utilization of the furnace gas as fuel, for chemical synthesis, and for pretreatment of the changes is discussed. Data from Elektrokemisk's recent research in the field are presented.

Abstract No. 154

Mineralogical and Geological Occurrence of Rhenium

S. R. Zimmerley, Research Labs., Kennecott Copper Co., Salt Lake City, Utah

(No abstract received)

Abstract No. 155

A Survey of the Different Methods for the Determination of Rhenium

Suzanne Tribalat, Laboratoire de Chimie Physique de la Faculté des Sciences, Paris, France

The study of the industrial recovery of rhenium became possible when one could determine exactly the element among large quantities of molybdenum. This paper surveys the recent works concerning the determination of rhenium. As for the determination of traces, the most sure and accurate method, tried out by thousands of analyses, is finally the extraction method of tetra phenylarsonium perrhenate, followed by the colorimetry of the thiocyanate complex, which we published a few years ago.

Abstract No. 156

Spectrophotometric Determination of Microgram Quantities of Rhenium

E. E. Malouf and **R. J. Heaney,** Research Labs., Kennecott Copper Co., Salt Lake City, Utah

(No abstract received)

Abstract No. 157

Some Recent Developments in the Halide and Ditertiary Arsine Chemistry of Rhenium

J. E. Fergusson and **R. S. Nyholm,** Dept. of Chemistry, University College of London, Gower St. WC 1, London England

Following a brief summary of the known halide complexes of the various oxidation states, recent work on the halide chemistry of tervalent and quadrivalent rhenium will be discussed. In particular, the stereochemistry of the halide complexes of rhenium III (d^4) will be discussed. The magnetism and stereochemistry will be correlated with the electron configuration. Then follows a survey of the ditertiary-arsine complexes formed by bivalent, tervalent, and pentavalent rhenium, which are, respectively, six covalent, six covalent, and eight covalent. The relationship of the spectra, magnetism, and coordination number with the electron configuration is examined.

Abstract No. 158

Spectrochemical Analysis of Rhenium Metal Powder

J. H. Allwein, Research & Development Dept., Chase Brass & Copper Co., Waterbury, Conn.

Qualitative and semiquantitative methods for the spectrochemical determination of trace impurities in commercially pure rhenium metal powder are discussed. The semiquantitative method is based on synthetic solution standards prepared from the purest grade of rhenium. The following techniques are evaluated: (*a*) the solution-direct current arc method; (*b*) the copper spark method; and (c) Zink's "vacuum cup" electrode method.

Abstract No. 159

The Crystal Chemistry of the Compounds of Rhenium with Transition Metals

N. V. Ageev and **V. Sh. Shehtman,** Academy of Science, Moscow

The compounds in the systems Re-Mo, Re-Mn, Re-Fe, *et al.*, have been studied. The single crystals of the δ-phase Re-Mo are received, from which the crystal-class symmetry and the dimensions of unit cell have been determined by x-ray method. The experimental study of the structure of two compounds in the Re-Mn and Re-Fe systems has been carried out. It is found that both these compounds have a structure isomorphous to well-known δ-phases. The conditions of formation of δ- and χ-phases in binary systems of rhenium with transition metals are analyzed. It is shown that the formation of χ-phases is determined mostly by the relation of the atomic radii of rhenium and the second component. The experimental data concerning the ordering of the atoms in the cells δ-phases and χ-phases in many binary systems on the base of rhenium are received.

Abstract No. 160

Metallurgical Processes for Recovery of Rhenium from Flue Dusts and Gases

E. E. Malouf, J. D. Prater, and S. R. Zimmerley, Research Labs., Kennecott Copper Co., Salt Lake City, Utah

(No abstract received)

Abstract No. 161

Process for Producing Pure Rhenium and Its Compounds

Marie-Louise Jungfleisch and **Henri Ruff,** Ets Ch. Bertolus, Bellegarde, France

A complete process for recovering rhenium in molybdenites is described. The process consists of roasting the molybdenite in two stages, washing gases evolved during the second stage, a liquid-liquid extraction producing a solution containing 80% of the initial rhenium, precipitation of the ammonium and potassium perrhenates, transformation of the latter into perrhenic acid by cationic exchange, and, last, reduction of ammonium perrhenate into metal and the purification of the metal until the rate of 99.9% by sublimating the heptoxide.

Abstract No. 162

Rhenium Powder Metallurgy and Fabrication of Wrought Products

J. H. Port, Chase Brass & Copper Co., Waterbury 20, Conn.

(No abstract received)

Abstract No. 163

Behavior of Rhenium during Hot-Working

Guy Lebert, Conservatoire National des Arts et Metiers, Paris, France

It is known that rhenium offers the peculiarity of being very rapidly work-hardened according to the deformation. We have thought that a hot working, if precautions were taken for preventing the oxidation of the metal, would permit larger deformations than the cold working would. From rhenium powders selected because of their purity, the influence of their granulometry was studied. After sintering, a swaging under controlled and reducing atmosphere was made. Thence, it became possible to obtain deformations reaching 30%.

Abstract No. 164

Powder Metallurgy of Refractory Alloys Containing Rhenium

Marie-Louise Jungfleisch, Et. Ch. Bertolus, Bellegarde, France, and **Jean Fabry,** Société Bocuze, Lyon, France

The fabrication of refractory alloys containing rhenium is presented: determination of the characteristics of powders giving the best results (essentially, average particle diameter), blending, pressing, sintering, swaging, and drawing of fine wires (0.001 in.) A study has been started to develop the applications of these alloys in the fields where their unique properties are the most valuable.

Abstract No. 165

Certain Physical Properties of Rhenium and Its Alloys

E. M. Savitski and **M. A. Tylkina,** The Institute of Metallurgy of the Academy of Sciences of the U.S.S.R., Moscow, U.S.S.R.

Studies have been made of recrystallization of rhenium, and of alloying with tungsten, nickel (in Ni-Cr alloys), and with titanium and its alloys. Rhenium additions improve both rooom and elevated temperature properties and increase the initial recrystallization temperatures. Solid solution tungsten alloys have increased workability and electrical resistance. Applications for rhenium alloys are promising for thermocouples, electrical contacts, and some vacuum tube parts. Results are given of a study of rhenium as a contact material.

Abstract No. 166

Rhenium and Transition Metals Phase Diagrams

E. M. Savitski and **M. A. Tylkina,** Institute of Metallurgy, Academy of Sciences of the U.S.S.R., Moscow, U.S.S.R.

Binary phase diagrams of rhenium with titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum, tungsten, manganese, and cobalt have been determined. A number of these alloy systems are characterized by the formation of intermetallic phases of the sigma or alpha-manganese types. Comparisons are made of these and other common features of the respective diagrams on the basis of the periodicity of the binary alloy additions.

Abstract No. 167

Deformation Characteristics of Rhenium Single Crystals

G. A. Geach, R. A. Jeffery, and **E. Smith,** Associated Electrical Industries, Ltd., Aldermaston, Berkshire, England

(No abstract received)

Abstract No. 168

The Workability and Mechanical Properties of Tungsten- and Molybdenum-Base Alloys Containing Rhenium

D. J. Maykuth, F. C. Holden, and **R. I. Jaffee,** Battelle Memorial Institute, Columbus 1, Ohio

Procedures for the fabrication of arc melted tungsten- and molybdenum-base alloys, containing 22-35 at. % rhenium, to strip, rod, and wire have been developed. Data are given on the recrystallization behavior and the effects of temperature on the tensile and bend properties of these alloys. The mechanism by which rhenium improves the ductility of tungsten and molybdenum is discussed.

Abstract No. 169

Evaluation of Rhenium as an Electrical Contact Material

V. E. Heil, T. C. Murphy, and **L. F. Neely,** P. R. Mallory & Co., Inc., Indianapolis, Ind.

(No abstract received)

Abstract No. 170

Thermocouples for 3000°C Using Rhenium Alloys

J. C. Lachman and **J. A. McGurty,** Aircraft Nuclear Propulsion Dept., General Electric Co., Cincinnati 15, Ohio

The disadvantages of limited temperature measurement capability and brittleness of rhenium/tungsten thermocouples have been overcome by the development of tungsten alloys containing rhenium. Various combinations of tungsten/rhenium alloys provide thermocouples useful to 3000°C with reasonable room temperature ductility for both wires. Calibration data and information on thermal emf stability are presented.

Abstract No. 171

Rhenium in Electronics

G. B. Gaines, Battelle Memorial Institute, Columbus 1, Ohio

The present status of the use of rhenium and rhenium alloys in electronic applications is described and, where possible, new applications are suggested with which the properties and the cost of rhenium are compatible. The information presented is based on the literature, personal correspondence, and new laboratory data. Of special interest are the present potential use of rhenium alloys in electron-tube and closely associated applications.

Abstract No. 172

Catalytic Hydrogenation of Sulfuretted Organic Compounds in the Presence of Rhenium Heptasulfide

Constantin Aretos and **Jean Vialle,** Lab of Chemistry, Faculté des Sciences, Caen, France

The rhenium heptasulfide used in this study was prepared according to W. Geilmann and H. Bode. At

a temperature of 100°C, and in the presence of acetic anhydride, it catalyzes the hydrogenation of the nitro-2 thiophéne into acetylamino-2 thiophene. At 200°C, the thiophenic nucleus is hydrogenated; in this manner, we prepared the thiolane and the methyl-2 thiolane. We studied at the same time the hydrogenation at 180°-200°C of three dithole-1, 2 thiones-3. We noticed an opening of the dithiole cycle and a partial desulfuration.

Abstract No. 173

On the Use of Pure or Alloyed Rhenium in Oxide Coated Cathodes

M. P. Warin, Centre national d'etudes des Telecommunications, Paris, France

Preliminary experiences using alkaline earth oxides either pressed with rhenium powder or as a coating on metallic rhenium having proved promising, experiments were undertaken to compare in a statistical fashion the behavior during life of high transconductance pentodes using either nickel alloyed with 1-10 % rhenium, or nickel alloyed with 4% tungsten, as the base metal of the oxide coated cathode. The 10% rhenium nickel bases gave satisfactory results even at a reduced temperature. At normal heater ratings, tubes of the same batch have yielded an average life of more than 20,000 hr.

Abstract No. 174

Electroplating of Rhenium

G. S. Root and **John Beach,** Battelle Memorial Institute, Columbus 1, Ohio

(No abstract received)

Abstract No. 175

Adhesion of Vapor Deposited Molybdenum Coatings

S. T. Wlodek (present address; Union Carbide Metals Co., Niagara Falls, N. Y.) and **John Wulff,** Dept. of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

The adherence of molybdenum coatings produced by the reduction of molybdenum pentachloride with hydrogen at 900°C was found to depend on the purity of the plating system and the chemical nature of the surface being plated. Adherent coatings could be produced under conditions where no oxide contamination was encountered only if the surface being plated did not contain constituents whose chlorides are more stable than those of molybdenum.

Abstract No. 176

Kinetics of the Oxidation of Pure Tungsten from 500° to 1300°C

E. A. Gulbransen and **K. F. Andrew,** Westinghouse Research Labs., Churchill Boro., Pittsburgh, Pa.

Kinetic studies were made on sheet and wire specimens from 500° to 1300°C and for pressures of 0.1 atm to 0.0013 atm. Crystal structure and photographic studies were made on the oxide scale and metal. At 500°C the reaction is probably controlled by diffusion processes in the oxide. Above 1200°C the reaction appears similar to the combustion of carbon with the rate of oxidation being limited by the access of oxygen to the surface. Localized edge-type of reaction is found over the temperature range.

Abstract No. 177

Preparation and Refining of Yttrium Metal by Y-Mg Intermediate Alloy Process

O. N. Carlson, J. A. Haefling, F. A. Schmidt, and **F. H. Spedding,** Institute for Atomic Research and Dept. of Chemistry, Iowa State University, Ames, Iowa

Yttrium metal was prepared by the reduction of YF_3 with calcium or lithium forming a low melting Y-Mg alloy. The magnesium was subsequently sublimed off to produce yttrium in sponge form which was arc melted into a solid ingot. A method of removing oxygen and fluorine from the alloy by extraction with fused yttrium salts is described. The results of electron beam melting and zone refining are also presented. Some properties of yttrium metal of 99.9% purity obtained by the extraction refining process are discussed.

INDUSTRIAL ELECTROLYTIC

Abstract No. 178

Graphite Anodes in Brine Electrolysis, IV. Effect of Anolyte *p*H on Corrosion Rate in Chlor-Alkali Cells

L. E. Vaaler, Development Lab., National Carbon Co., Division of Union Carbide Corp., Niagara Falls, N. Y.

The effect of anolyte *p*H on cell efficiency and anode corrosion rate was studied in an experimental chlorine cell. With increasing *p*H, the expected decrease in current efficiency was observed with a resultant increase in the amounts of oxygen and carbon dioxide evolved. The relative increase in oxygen evolution is far greater than the carbon dioxide evolution. The results can be explained by a mechanism whereby the oxygen is formed from physically adsorbed oxygen, while carbon monoxide is formed from chemisorbed oxygen, and oxidized to carbon dioxide by oxygen or dissolved chlorine.

Abstract No. 179

Chemical Engineering Studies on the Decomposition Packed Tower of the Amalgam on the Chlorine-Caustic Industry

Shinzo Okada, Shiro Yoshizawa, and **Fumio Hine,** Dept. of Industrial Chemistry, Kyoto University, Kyoto, Japan

Kinetics on the amalgam decomposition in the cause of the local cell consist of Na-Hg(Y)/NaOH aq. (X)/H_2-graphite with emphasis on the hydrogen overpotential; the chemical engineering considerations of the decomposition tower and how to design the tower are described. This study involves representations concerning the H.T.U. and the N.T.U. of the amalgam decomposition tower from an electrochemical point of view, i.e., this tower differs from common packed towers which may be operated under the control of diffusion process.

Abstract No. 180

A Small-Scale Electro-Organic Chemical Plant

J. W. Drew and **G. J. Moll,** Ciba Pharmaceutical Products, Inc., Summit, N. J.

An electro-organic reaction unit for batch preparation of pharmaceutical intermediates on a pilot-plant and semi-commercial scale is described. Because the use of the electro-organic technique is uncommon outside of the laboratory, details of cell construction, arrangement, and instrumentation are given, with emphasis on design for versatility, safety, and accurate process control.

Examples are given of the complete reduction of an imide (N,N-dimethylaminoethyl tetrachlorophthalimide to N,N-dimethylaminoethyl tetrachloroisoindoline) using a lead cathode, and of the bimolecular reduction of a ketone to a pinacol (3-acetyl pyridine to 2, 3-bis(3-pyridyl)-2,3-butanediol) at a tin cathode.

Abstract No. 181

Intermediate Temperature Fuel Cells

G. V. Elmore and **H. A. Tanner,** Charles F. Kettering Foundation, Box 215, Yellow Springs, Ohio

New types of aqueous hydrogen-oxygen fuel cells operating at temperatures above 100°C, at atmospheric pressure, have been studied. An advantage of these cells is the removal of product water by vaporization. A cell operating in an alkaline electrolyte and a cell utilizing an acid electrolyte have been developed. Porous electrodes which have been treated with teflon have proved to be effective in resisting electrolyte penetration. Current densities in the range of 50 to 100 ma/cm^2 at 0.5 v have been achieved. The electrode mechanisms are discussed.

Abstract No. 182

Electrolytic Reduction of Thorium Oxide

L. H. Meyer, Savannah River Laboratory, E. I. du Pont de Nemours & Co., Aiken, S. C.

Thorium metal was prepared by electrolytic reduction of thorium oxide in two systems, a fused KF-ThF_4 mixture and a fused NaCl-KCl-$ThCl_4$ mixture. The average decomposition potential measured in both systems was 1.92 v. Electrolysis in the fluoride melt proved to be a superior process, the metal product having higher purity and larger average particle size than the product from the chloride melt. In addition, the recovery of thorium from recycle streams proved to be much simpler in the fluoride process than in the chloride process. The feasibility was demonstrated for all the essential steps of a complete process for production of the metal in the fluoride system.

Abstract No. 183

Metal Mists and Aluminum Losses in the Hall Process

W. E. Haupin, Alcoa Research Labs., P.O. Box 772, New Kensington, Pa.

Reaction of aluminum with Hall cell electrolyte forms aluminum monofluoride and sodium which dissolve in some form to give the bath a reducing capacity equivalent to a free aluminum content of about one tenth per cent. The so-called "metal mist" forms in the presence of moisture and consists of hydrogen bubbles containing a small partial pressure of aluminum monofluoride, sodium and sodium tetrafluoroaluminate. Increasing the NaF/AlF_3 ratio of the electrolyte increases the sodium and decreases the aluminum monofluoride partial pressure, but sodium has a much higher partial pressure; hence, a low NaF/AlF_3 ratio is desirable to minimize metal reoxidation. Carbon dioxide is abundant in the anode gas of a smelting cell and is soluble in the bath. It oxidizes the free metal both in and over the bath. The rate of this reoxidation appears to be controlled by the rate of diffusion and convection of dissolved metal away from the metal-bath interface.

Abstract No. 184

Preparation of Boron from Boron Carbide

D. R. Stern, American Potash & Chemical Corp., 3100 East 26th St., Los Angeles 23, Calif.

A process to prepare elemental boron from boron carbide is presented. Included is evidence that the process is one of anodic transfer. Boron of at least 99.8% purity can be made directly from technical grade materials. Purity is a function of electrolysis voltages

and boron carbide purity. Current efficiencies in excess of 95% are obtained and preferred electrolysis conditions are stated.

Abstract No. 185

Lead Dioxide Anode in the Preparation of Perchlorates

K. C. Narasimham, S. Sundararajan, and **H. V. K. Udupa,** Central Electrochemical Research Institute, Karaikudi-3, S. India

The technique of deposition of lead dioxide on graphite or carbon base material, developed in this laboratory earlier, has now been used for obtaining suitable anodes in the preparation of sodium perchlorate from sodium chlorate. Extensive investigation has been carried out and results presented on the successful use of this type of anode in presence of certain addition agents as a replacement for platinum anode.

The influence of anodic current density, temperature, pH, current concentration, and duration of electrolysis on the current efficiency of perchlorate formation has been studied. Current efficiency was found to depend on anode surface transformation which took place on repeated use. Such changes could be observed visually and anode potential measurements confirm the same.

High current efficiency could be obtained even under slightly alkaline conditions of electrolysis but addition of fluoride improved the results. Addition of fluoride together with sulfate (as sulfuric acid) had the maximum effect on current efficiency under acidic conditions of pH.

THEORETICAL ELECTROCHEMISTRY—INDUSTRIAL ELECTROLYTIC

Abstract No. 186

The Measurement of Polarization

Ernest Yeager, Dept. of Chemistry, Western Reserve University, Cleveland 6, Ohio

Well established techniques for measuring the potentials of working electrodes are reviewed and evaluated in terms of application to the following: (*a*) polarization measurements under highly controlled conditions which are conducive to a detailed analysis of the electrode processes, and (*b*) polarization measurements in the actual systems of direct interest to electrochemical engineers for the purpose of a general analysis of the sources of polarization in the working system. Application of both steady-state and transient methods are discussed.

Abstract No. 187

Applied Electrochemical Kinetics

Paul Delahay, Dept. of Chemistry, Louisiana State University, Baton Rouge 3, La.

The necessity for quantitative knowledge on activation polarization (i.e., polarization after correction for mass transfer) is stressed for control of industrial processes. It is shown that the essential ideas of chemical kinetics can be transposed to the interpretation of polarization measurements. In many instances, polarization curves can be interpreted in terms of two kinetic parameters, the exchange current density (or standard rate constant) and the transfer coefficient. Methods of calculation are outlined. Reaction mechanisms and reaction orders are established from the study of these two kinetic parameters. The influence of the electrolyte composition and the nature of the electrode are analyzed on the basis of double layer and specific electrode (adsorption, etc.) effects. Complications caused by a blocking layer of adsorbed substances (additives or impurities) are finally examined. Examples, taken from processes of industrial significance whenever possible, are given for each method of attack. Sources and critical evaluation of data are discussed.

Abstract No. 188

Electrocrystallization and Surface Films

D. A. Vermilyea, Research Lab., General Electric Co., Schenectady, N. Y.

Crystals almost always grow or evaporate by the addition or removal of atoms at surface steps. Also, surface reactions depend critically on the precise atomic arrangement of the surface. Solid surfaces are thus far from uniform in their reactivity. The inferences concerning electrode reactions which may be drawn from this fact are discussed, with particular emphasis on anodic oxide films and electrolytic crystal growth.

Abstract No. 189

Mass Transport in Electrolysis, Hydrodynamic Factors

Norbert Ibl, Federal Technological Institute, Zurich, Switzerland

The general mechanism of solution-side mass transport is reviewed. The theory of convective mass transport in electrolysis is outlined (dimensional analysis, boundary layer theory). The quantitative evaluation of limiting currents and interfacial concentrations, based on theoretical and experimental relationships, is discussed for a variety of common hydrodynamic situations and usual geometries: laminar and turbulent flow along a plate; rotating disk; rotating cylinder; natural convection, gas-evolving electrodes.

Abstract No. 190

Heat Transport and Temperature Distribution in Cells

T. R. Beck, American Potash and Chemical Co., Henderson, Nev.

Equations are presented that describe the location and the magnitude of the heat sources and sinks in an electrolytic cell. Quantitative relations describing the transport of heat within cells and to surroundings are also developed. Application of these equations to the geometry and physical properties of electrolyte and cell materials of particular cells permits calculation of such quantities as electrolyte temperature, electrode surface temperature, amount of additional heat required, amount of heat to be removed, and amount of insulation required. Examples of application to commercial electrochemical cells are given.

Abstract No. 191

Effect of Geometry on Current Distribution in Industrial Electrolytic Cells

Scott Lynn, Dow Chemical Co., Western Div., Pittsburg, Calif., and **C. W. Tobias,** Dept. of Chemistry, University of California, Berkeley 4, Calif.

The local rate of an electrode reaction depends on the distribution of current over the electrode surface. Quantitative consideration of this distribution and its effect on cell performance is required for rational cell design and for the optimization of operational procedures. The potential distribution in geometries typical of electrode arrangements in industrial cells is subjected to mathematical analysis. Numerical solutions for the more complex cases are obtained by the relaxation method using high-speed digital computers. The effect of polarization is included, and time changes in geometry due to electrode wear or solid deposits are also considered.

Abstract No. 192

Effect of Nongeometric Factors on Current Distribution

E. A. Grens and **C. W. Tobias,** Dept. of Chemistry, University of California, Berkeley 4, Calif.

Conductive properties of the electrodes and of the electrolyte regime between the electrodes can be the controlling factors in influencing current distribution. Electrode potentials and conductances depend on transport of reacting species and of products, and therefore the current distribution may be influenced by hydrodynamic factors. Some well-known examples taken from industrial practice are subjected to analysis. An apparent lack of correspondence between laboratory and plant scale performance may be resolved by considering criteria of dynamic similarity.

Abstract No. 193

Electrode Materials and Materials of Construction

M. S. Kircher and **J. E. Currey,** Hooker Chemical Corp., Niagara Falls, N. Y.

Process characteristics such as equilibrium potentials and overvoltages, electrolyte and product properties, temperature, etc., are considered in relation to materials of construction. Examples of electrode materials and cell construction materials used for some of the more important industrial cells are reviewed. Relationships between materials and design possibilities are discussed considering cost and availability as well as physical and chemical properties of materials. Specific examples of chlor-alkali cell design are included to show how a material may be selected for a given cell design and, conversely, how a cell design is derived to meet the requirements of an important material of construction. Expected trends in future cell designs are discussed with reference to availability of new materials.

Abstract No. 194

The Problem of Scale Up of Electrolytic Processes

R. B. MacMullin, R. B. MacMullin Associates, Niagara Falls, N. Y.

The industrial objective is first analyzed in full scope —feed preparation, electrolysis, and recovery of products—on the basis of existing information or analogies. A preliminary idea of cell type and capacity results, which is then scaled down to arrive at a suitable minimum prototype cell for test. Areas of ignorance are thus defined and programmed for exploration. After testing each model, the original objectives are reviewed, and the size and design of the next model is decided on the basis of scale down of a commercially desirable cell as well as scale up from the last model. The technique of complete cell design is discussed in detail and illustrated with practical applications. Procedures for economic evaluation are described.

Abstract No. 195

Measurements on a Plant Scale

C. J. Dobratz, Dow Chemical Co., Western Div., Pittsburg, Calif.

Measurements on a plant scale are complicated by problems not encountered normally in the laboratory. These are discussed along with the techniques of measurements on a plant scale of some of the operating variables peculiar to electrolytic cells. Recent developments in the use of statistical methods and automatic computers for the planning of experiments and

the treatment of data are described. Examples are given of the application of these methods in an electrolytic caustic and chlorine plant.

THEORETICAL ELECTROCHEMISTRY

Abstract No. 196

Double Layer Structure and Relaxation Methods for Fast Electrode Processes

Hiroaki Matsuda and **Paul Delahay,** Dept. of Chemistry, Louisiana State University, Baton Rouge, La.

An equation is derived for the overvoltage-time characteristic in the double pulse galvanostatic method, the structure of the double layer being considered in the boundary value problem. It is shown that a previous treatment without consideration of the double layer structure can be applied with simple modifications in the expression of the measured exchange current density. The measured transfer coefficient is seriously in error in case of strong repulsion and, especially, attraction of the discharged species in the diffuse double layer. Abnormally high transfer coefficients recently reported by other investigators are interpreted. A detailed mathematical analysis is given.

The elements of the equivalent circuit for the faradaic impedance are derived, due consideration being given to the structure of the double layer in the solution of the boundary value problem. It is shown that the classical theory is applicable but that measured exchange current densities and transfer coefficients must be corrected. The phase angle which is also affected can exceed $\pi/4$ when the reactants are strongly attracted in the diffuse double layer. Comparison is made with a similar treatment for the galvanostatic double pulse method.

Abstract No. 197

The Interpretation of Measurements of Potential Decay on Open Circuit

P. C. Milner, Bell Telephone Labs., Inc., Murray Hill, N. J.

Observations of the change in electrode potential as a function of time on open circuit have proved to be a useful method for the study of the kinetics of electrode reactions and the capacitance of the electrical double layer. The interpretation of such observations may, however, be complicated by the presence of capacitative effects resulting from faradaic processes. Consideration of these effects is included in the theory of open-circuit decay, and it is shown that in certain cases such effects are virtually indistinguishable from the capacitance of the electrical double layer and that they may be of surprising importance. The analysis of decay

measurements is also considered, and a new method, which overcomes a number of objections to previous procedures, is described.

Abstract No. 198

Cathodic Processes on Passive Zirconium

R. E. Meyer, Chemistry Div., Oak Ridge National Lab., Oak Ridge, Tenn.

Measurements were made of the rates of reduction of Cu^{++}, H_2O_2, H^+, and O_2 on passive zirconium in acid solutions of sodium sulfate at temperatures ranging from 25° to 85°C. Rates of reduction at constant potential of these oxidizing agents tended to decrease with time, and Tafel slopes tended to increase with time. The kinetic orders of reduction were determined from potentiostatic experiments in which the current was determined as a function of concentration. Unit orders or nearly unit orders were observed with oxygen reduction, and fractional orders from about 0.5 to 0.65 were observed for Cu^{++} and H_2O_2. Possible mechanisms are suggested in which charge transfer through the film is assumed to play a predominant role.

Abstract No. 199

Kinetics of Anodic Processes in Carboxylic Acids

B. E. Conway and **M. Dzieciuch,** Dept. of Chemistry, University of Ottawa, Ottawa, Canada

Kinetics of the Kolbe type of reaction have been studied at gold, palladium, and platinum for anodic discharge of formate ions and trifluoroacetate ions. Linear Tafel lines are observed over three decades of current density, and the slopes are discussed. Galvanostatic charging and open-circuit decay curves indicate formation of adsorbed intermediates during the anodic reactions. Coulombic efficiencies for product formation have been determined and are discussed in relation to reaction mechanisms.

Abstract No. 200

Faradaic Rectification with Control of Alternating Potential Variations—Application to Electrode Kinetics for Fast Processes

Hiroaki Matsuda and **Paul Delahay,** Dept. of Chemistry, Louisiana State University, Baton Rouge, La.

In this method, the potential of an electrode at which a fast charge transfer process occurs is varied about the equilibrium potential according to a sinusoidal function of time. The resulting alternating current includes a rectification component because of the asymmetry of the current-potential curve. An equation is derived for this faradaic rectification current, and it is shown that the exchange current density and the transfer coefficient can be determined from the variations of the

rectification current with time. Two methods of calculation are discussed. A correction for the double layer structure in the solution of the boundary value problem is derived. Conditions for frequency and circuit resistance are established. Finally, it is shown that, because the double layer capacity is in parallel with the faradaic impedance, the alternating variations of potential should in effect be controlled, except for very fast processes, even when the cell current is controlled. Analysis of faradaic rectification at controlled current developed by previous investigators thus may correspond to conditions which are seldom achieved.

Abstract No. 201

The Influence of Cations on the Differential Capacity of the Mercury Dropping Electrode in Methanol and Ethanol Solutions of Electrolytes

S. Minc, Dept. of Electrochemistry, University of Warszawa and Dept. of Electrochemistry, Polish Academy of Sciences, Warszawa, Poland

Differential capacities of the electrical double layer in region of cathodic polarization of LiCl, NaCl, KCl, $MgCl_2$, $CaCl_2$, $SrCl_2$ solutions in methanol have been measured. The effect of concentrations of the KF and LiCl solutions in methanol, ethanol, and water on the differential capacity have been determined. In addition the potential of desorption of Br^- ions in methanol in presence of Li^+ ions and K^+ ions have been investigated. The results give evidence that some cations, especially those of low polarizing ability, are specifically adsorbed at the mercury surface.

Abstract No. 202

Irreversible Thermodynamics in Electrochemistry

A. J. deBethune, Chemistry Dept., Boston College, Chestnut Hill 67, Mass.

The Onsager thermodynamics provides a unified approach to electrolytic systems out of equilibrium, such as concentration cells with transference, initial and final emf's of thermal cells, and thermal diffusion (Soret effect) of ions. For concentration cells, the method justifies the classical results of Nernst. For nonisothermal systems, the product S^*dT is the thermodynamic driving force where S^* is the entropy transported reversibly from the hot to the cold heat reservoir. The emf of a concentration cell, the initial emf of a thermal cell, and the Soret coefficient are determined by the ratios of the reversible fluxes of matter to electricity, of entropy to electricity, and of entropy to matter, respectively.

Abstract No. 203

Potentials in the System, Cr (II)-Cr (III), at Various Electrodes

K. B. Morris, Institute of Technology, Air University, Wright-Patterson AFB, Ohio

Potentials have been measured for the Cr (II)—Cr (III) system at gold, graphite, mercury, and platinum electrodes. Gold and mercury appear to be the best electrodes for two reasons, namely, (*a*) measured potentials are fairly close to theoretical potentials and (*b*) plots of log $[Cr^{+3}]/[Cr^{+2}]$ against emf are linear for those electrodes. The same plot for platinum is linear but the experimental potentials are roughly 300 mv lower than the theoretical potentials.

Abstract No. 204

Electrochemical Study of Metallic Oxides in Fused Lithium Chloride-Potassium Chloride Eutectic

H. A. Laitinen and **B. B. Bhatia,** Noyes Chemical Lab., University of Illinois, Urbana, Ill.

Owing to the relatively high solubilities of metal oxides the applicability of metal oxide electrodes to the measurement of oxide ion activity is limited to solutions containing oxide ion in concentrations comparable with, or greater than, that contributed by dissolution of the oxides. This limit is $10^{-4}M$ or higher, depending on the system. The relatively high solubility of heavy metal oxides in this solvent is attributed to the great complexing tendency of chloride ion. It is probable that these oxides would be much less soluble in nitrate and sulfate metals and thus their utility as acidity electrodes can be extended to lower oxide concentrations.

Abstract No. 205

Gas-Phase Charged and Electrolytically Charged β-Pd-H Alloys

J. P. Hoare, Scientific Lab., Ford Motor Co., Dearborn, Mich.

Open-circuit potential-time curves were obtained from β-Pd-H electrodes in acid solution made from dry Pd wire in hydrogen gas and from Pd wire cathodes in sulfuric acid solution. Hydrogen content of the wires was determined using ceric sulfate solutions. Evidence is presented to suggest the existence of two kinds of β-Pd-H alloys. Charging mechanisms are suggested.

Abstract No. 206

Kinetics of Cathodic Hydrogen and Deuterium Evolution

B. E. Conway, Dept. of Chemistry, University of Ottawa, Ottawa, Canada

Isotopic ratios R of exchange currents for hydrogen and deuterium evolution have been obtained for palladium, platinized platinum, and copper and are discussed in relation to previous results for other metals. When surface coverage effects are considered, R has the minimum values of 7 or 2 for atom-ion and recombination desorption reactions, respectively, while for slow discharge of oxonium ions R has the minimum value 2.2 in agreement with experiment for mercury. R values for various metals are discussed in terms of rate-determining mechanism.

Abstract No. 207

Behavior of Hydrogen at Oxidized Platinized Platinum Electrodes

N. J. Ward (present address: General Chemical Div., Allied Chemical and Dye Corp., Baton Rouge, La.) and **T. C. Franklin,** Chemistry Dept., Baylor University, Waco, Texas

A study was made of the kinetics of the reaction of hydrogen with a hydrogen depleted platinized platinum electrode in order to get an idea of the mechanism of the reaction. The kinetics was investigated as functions of the pressure of the hydrogen and the area of the electrode. The electrode area was varied by: (*a*) varying the length of the electrode; (*b*) varying the coulombs of electricity passed in plating the electrode; and (c) poisoning the electrode with acetonitrile. From this data was deduced a possible mechanism of reaction of platinized platinum electrodes with hydrogen in solution in aqueous sulfuric acid.

Abstract No. 208

Transient Strain Induced Electrode Potentials

Eric Baum, W. F. Seyer, and **Ken Nobe,** Dept. of Engineering, University of California, Los Angeles 24, Calif.

Transient potentials produced when copper and zinc-plated copper wires are elastically strained in $CuSO_4$ and $ZnSO_4$ solutions, respectively, were investigated. The potential response on loading was almost instantaneous and decayed back close to the original value within several seconds. The unloading response was similar to loading but of opposite sign. The amplitude of the response was approximately proportional to the load. Theoretical considerations of the electrical double layer predict the experimental results obtained.

Abstract No. 209

Electrocapillary Studies on Solid Metals

D. N. Staicopoulos, Engineering Research Lab., Engineering Dept., E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

The use of a revolving-cup friction-measuring apparatus has made possible a study of the adsorption/desorption of ionic species on solid metal/solution interfaces, as a function of applied electrical potential. The results of this study reveal similarities between the friction characteristics at solid metal surfaces and the surface tension of liquid metals under the influence of an applied electrical potential. Specific adsorption and/or chemisorption of ionic species onto solid metal surfaces can thus be detected from the specific changes in the friction/potential characteristics.

Abstract No. 210

A New Model for Evaluating the Conductivities of Dispersions

R. E. Meredith (present address: Chemical Engineering Dept., Oregon State College, Corvallis, Oreg.) and **C. W. Tobias,** Lawrence Radiation Lab. and Dept. of Chemical Engineering, University of California, Berkeley, Calif.

Electrical conductivity measurements have been made on emulsions where the volume fractions and the conductivities of the two phases vary over a wide range. The data obtained indicate that neither Maxwell's nor Bruggeman's relation adequately predicts the effective conductivities of mixtures above a dispersed-phase volume fraction of about 0.2. A new model is proposed which corrects for some of the field interaction that exists between particles in concentrated dispersions of spherical or nonspherical particles.

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INDEX TO AUTHORS

(The number in the right hand column is the abstract number used in the Technical Program and in the Abstracts.)

	Abstract No.
Adams, I.	53
Agarwal, J. C.	140
Ageev, N. V.	159
Allred, W. P.	88
Allwein, J. H.	158
Altenpohl, Dietrich	6
Andrew, K. F.	176
Antonov-Romanovsky, V. V.	68A
Aretos, Constantin	172
Arpiarian, N.	55
Astier, J.	147
Aven, M.	65
Avinor, M.	57
Baker, D. H., Jr.	125
Barnes, C. E.	38
Barnes, C. R.	18
Barson, Fred	115
Bate, R. T.	94
Baum, Eric	208
Beach, John	174
Becherer, H. K.	120
Beck, T. R.	190
Belz, L. H.	10
Bender, B. G.	118, 119
Bennett, A.	27
Bennett, A. I.	83
Bernard, W. J.	26
Bernstein, L.	118, 119
Berry, R. W.	25
Bhatia, B. B.	204
Blakeslee, A. E.	106
Block, F. E.	124
Bourke, R. C.	96
Breitenstein, J. S.	144
Brophy, V. A.	60
Brown, D. C.	134
Budnick, J. I.	12
Burnham, J.	1
Busen, Karl	107
Butler, K. H.	43
Callinan, T. D.	33
Carlson, O. N.	126, 177
Catotti, A. J.	29
Cattoir, F. R.	125
Cavanagh, R. L.	148
Colburn, J.	112

Abstract No.

Collin, F. C. 153
Convey, John 133
Conway, B. E. 199, 206
Cook, J. S. 37
Cooper, H. W. 104
Curie, D. 55, 56
Curie, G. 55, 56
Currey, J. E. 193
Cusano, D. A. 63

deBethune, A. J. 202
Delahay, Paul 187, 196, 200
Dobratz, C. J. 195
Donahue, D. J. 108
Dormsjo, T. O. 143
Doucette, E. I. 104
Dreeben, Arthur 70
Drew, J. W. 180
Dubinin, V. G. 68A
Dzieciuch, M. 199

Eby, J. E. 45
Ellis, R. C., Jr. 78
Elmore, G. V. 181

Fabry, Jean 164
Faria, Sixdeniel 68
Farrell, J. W. 128
Faust, J. W., Jr. 79, 81, 84
Fergusson, J. E. 157
Ferrante, M. J. 124
Fincham, C. J. B. 13
Fisher, J. S. 22
Flint, P. S. 113
Fock, M. V. 68A, 77
Franklin, T. C. 207
Freeman, Horace 145
Frisco, L. J. 32
Frosch, C. J. 97
Fuller, C. S. 90

Gaines, G. B. 171
Geach, G. A. 167
Geesner, C. R. 18
Genco, J. I. 91
Gerlach, L. 110
Gershenzon, M. 97, 98
Gibbs, D. F. 97
Gill, R. W. A. 58
Goering, H. L. 92
Goldberg, Paul 67, 68, 69
Gorton, H. C. 99
Gow, John 115
Grens, E. A. 192
Gresh, M. 16, 25

Abstract No.

Guéret, P. 55
Gulbransen, E. A. 176
Guldner, W. G. 11

Haake, C. H. 44
Haberecht, R. 110
Haefling, J. A. 177
Hains, D. J. 137
Halpin, A. T. 67
Hamby, D. C. 19
Hamilton, D. R. 80
Hardy, A. E. 64
Haupin, W. E. 183
Heaney, R. J. 156
Heil, V. E. 169
Himes, R. C. 91, 92
Hine, Fumio 179
Hoare, J. P. 205
Holden, F. C. 168
Houtz, C. C. 11, 30
Hozak, N. L. 37
Huber, F. 20
Huebler, J. 136
Hummers, W. S. 54
Hunter, M. S. 9
Hyde, R. W. 142

Ibl, Norbert 189

Jaek, I. W. 77B
Jaffe, P. M. 73, 74
Jaffee, R. I. 168
James, B. D. 113
James, W. J. 129
Jeffery, R. A. 167
Jenny, A. L. 15
Jensen, R. V. 95
Jerome, C. W. 46
John, H. F. 79, 81
Johnson, P. D. 48
Jordan, E. L. 108
Jungfleisch, Marie-Louise 161, 164

Kaiser, W. 90
Kamyszek, K. 75
Karlik, S. 16
Kenahan, C. B. 129A
Keyser, N. H. 152
Keywell, Frank 103
Kircher, M. S. 193
Kirkland, T. G. 146
Klick, C. C. 59
Klement, F. D. 54
Knight, H. T. 17
Kobuke, Yoshimasa 50

Abstract No.

Koller, L. R. 62
Komjathy, S. 130
Kulwicki, B. M. 93
Kushida, Takashi 50

Lachman, J. C. 170
Laitinen, H. A. 204
Lambe, J. 39
Lane, R. 27
Langlais, D. G. 102
Langston, B. G. 141
Law, J. M. 24
Lawson, W. D. 100
Lebert, Guy 163
Lehovec, Kurt 2, 105
Longini, R. L. 83
Lougher, E. H. 96
Lubker, R. A. 139
Lüdja, G. G. 77B
Lushchik, Ch. B. 77B
Lushchik, N. E. 77B
Lynn, Scott 191

Mackintosh, I. M. 109
MacMullin, R. B. 194
Malouf, E. E. 156, 160
Markham, J. J. 42
Mason, D. R. 37, 38, 93
Masuda, Isoo 50
Matsuda, Hiroaki 196, 200
Maykuth, D. J. 168
McGahan, T. E. 111
McGurty, J. A. 170
McLean, D. A. 21
Meeks, Earl 107
Mehnert, R. A. 104
Mellichamp, J. W. 53
Meredith, R. E. 210
Merrill, T. W. 127
Meyer, L. H. 182
Meyer, R. E. 198
Meyerhofer, D. 95
Mikulyak, R. M. 98
Miller, J. F. 92
Milner, P. C. 197
Minc, S. 201
Mohler, D. 5
Moll, G. J. 180
Moody, P. L. 85
Moore, R. 112
Morris, K. B. 203
Moss, R. 84
Mullin, J. B. 87
Mudar, J. 39, 75
Murphy, T. C. 169

Abstract No.

Narasimham, K. C. 185
Nechtow, Marshall 103
Neely, L. F. 169
Nicholson, H. 84
Nobe, Ken 208
Nudelman, S. 39, 75
Nyholm, R. S. 157

Okada, Shinzo 179
O'Nan, T. C. 23
Orme, J. E. 14
Osiko, V. V. 77A
Owen, C. V. 126

Parks, A. M. 31
Paskell, Ernest 120
Pihl, Carl 105
Pitman, H. W. 19
Platner, J. 146
Port, J. H. 162
Potter, R. M. 61, 65
Prater, J. D. 160
Prokhorov, A. M. 68A

Rairden, J. R. 7, 8
Rajala, B. R. 131
Reed, T. F. 140
Reid, F. J. 99
Rice, O. R. 138
Richards, W. C. 24
Root, G. S. 174
Ropp, R. C. 52
Rosi, F. D. 95
Ross, H. U. 135
Rothschild, S. 58
Ruff, Henri 161
Ruscetta, R. A. 15
Russ, Robert 4

Salomon, T. 35
Samelson, Harold 60
Sangster, R. C. 86
Savitski, E. M. 165, 166
Schlain, David 129A
Schmidt, F. A. 177
Schmidt, P. F. 20
Schwartz, N. 17, 25
Schwarz, K. K. 77B
Schwarz, R. F. 20
Schwuttke, G. H. 89
Seidensticker, R. G. 80
Seyer, W. F. 208
Sharbaugh, A. H. 34
Shehtman, V. Sh. 159
Shipley, E. H. 140
Shtasel, A. 17

Abstract No.

Simon, R. 96
Smith, A. L. 51
Smith, A. W. H. 36
Smih, E. 167
Smith, F. A. 100
Smith, I. L. 65
Smith, R. C. 82
Smith, W. J. 83
Sollenberger, C. L. 146
Solomon, A. L. 69
Spector, C. J. 111
Spedding, F. H. 177
Staicopoulos, D. N. 209
Stambaugh, E. P. 91
Stamets, R. J. 28
Stavik, O. 116
Stephens, F. M., Jr. 141
Stephenson, Donald 4
Stern, D. R. 184
Stotler, H. H. 139
Straumanis, M. E. 129
Strauss, A. J. 85
Strock, L. W. 76
Sundararajan, S. 185

Tanner, H. A. 181
Thomas, M. J. B. 46
Thornton, W. A. 66
Thurmond, C. D. 90
Tobias, C. W. 191, 192, 210
Towner, P. F. 9
Tragert, W. E. 7, 8
Trapeznikova, Z. A. 68A
Tribalat, Suzanne 155
Trytten, G. 39
Turner, D. R. 101
Tylkina, M. A. 165, 166

Udupa, H. V. K. 185
Udy, M. C. 151
Uehara, Yasuo 40, 50
Urban, M. J. 25

Vaaler, L. E. 178
Van Thyne, R. J. 131
Van Uitert, L. G. 47
Vermilyea, D. A. 188
Vialle, Jean 172
Villani, G. J. 13
Vinokurov, L. A. 77

Wachtel, A. 71, 72
Walde, H. 149
Ward, N. J. 207
Warin, M. P. 173
Warren, W. B. 118, 119

(Index cont'd)

Abstract No.

Weeks, A. D. 123
West, R. A. 28, 29
Wild, R. 150
Willardson, R. K. 88
Williams, F. E. 41, 49
Wirtz, L. H. 33
Wlodek, S. T. 132, 175
Wolff, G. A. 53
Wulff, John 175

Yeager, Ernest 186
Yoshizawa, Shiro 179
Young, A. S. 100
Young, L. 3, 14

Zimmerley, S. R. 154, 160

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